Design & Fabrication of Eco Friendly Cooling System

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Abstract— Magnetic refrigeration which is a method of refrigeration based on the magneto caloric effect and hence it is an efficient method in today's world, which actually can bring fluctuations in energy saving factors. This problem with using pure gadolinium as the refrigerant material is that it does not exhibit a strong magneto caloric effect at room temperature. More recently, however, it has been discovered that arc-melted alloys of gadolinium, silicon, and germanium are more efficient at room temperature. Using the magneto caloric effect for refrigeration purposes was first investigated in the mid-1920's but is just now nearing a point where it could be useful on a commercial scale.1 The main difference associated with this process is that it is void of a compressor. The compressor is the most inefficient and expensive part of the conventional gas compression system. In place of the compressor are small beds containing the magneto caloric material, a small pump to circulate the heat transfer fluid, and a drive shaft to move the beds in and out of the magnetic field.

Key words: Magnetic Refrigeration, Gadolinium, Magneto Caloric Effect

I. INTRODUCTION

Modern society largely depends on readily available refrigeration methods. Up till now, the conventional vapor compression refrigerators have been mainly used for refrigeration applications. Nonetheless, the conventional refrigerators – based on gas compression and expansion – are not very efficient because the refrigeration accounts for 25% of residential and 15% of commercial power consumption. Moreover, using gases such as chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) have detrimental effects on our environment. Recently, the development of new technologies – such as magnetic refrigeration – has brought an alternative to the conventional gas compression technique.

The Magnetic Refrigeration at room temperature is an emerging technology that has attracted the interest of researchers around the world. Such a technology applies the Magneto Caloric Effect which was first discovered by Warburg (Bohigas, 2000; Zimm, 2007). In 1881, Warburg noticed an increase of temperature when an iron sample was brought into a magnetic field and a decrease of temperature when the sample was removed out of it. Thus, the magneto caloric effect is an intrinsic property of magnetic materials; where it is defined as the response of a solid to an applied magnetic field which appears as a change in its temperature. Such materials are called magneto caloric materials. The ultimate goal of this technology would be to develop a standard refrigerator for home use. The use of Magnetic Refrigeration has the potential to reduce operating and maintenance costs when compared to the conventional method of compressor-based refrigeration. The Magneto Caloric Effect is a magneto thermodynamic phenomenon in which a temperature change of a suitable material is caused by exposing the material to a changing magnetic field. This is also known by low temperature physicists as adiabatic demagnetization.

In this context, we have worked on topic "Peltier cooling effect" which works on thermoelectric refrigeration, aims to provide cooling by using thermoelectric effects rather than the more prevalent conventional methods like 'vapour compression cycle' or the 'vapour absorption cycle'. There are three types of thermoelectric effect: The Seebeck effect, the Peltier effect, the Thomson effect. From these three effects, Peltier cooler works on the Peltier effect; which states that when voltage is applied across two junctions of dissimilar electrical conductors, heat is absorbed from one junction and heat is rejected at another junction.

II. SOLAR MECHANICAL REFRIGERATION

Solar mechanical refrigeration uses a conventional vapor compression system driven by mechanical power that is produced with a solar-driven heat power cycle. The heat power cycle usually considered for this application is a rankine cycle in which a fluid is vaporized at an elevated pressure by heat exchange with a fluid heated by solar collectors. A storage tank can be included to provide some high temperature thermal storage. The vapor flows through a turbine or piston expander to produce mechanical power. The fluid exiting the expander is condensed and pumped back to the boiler pressure where it is again vaporized. The efficiency of the Rankine cycle increases with increasing temperature of the vaporized fluid entering the expander.

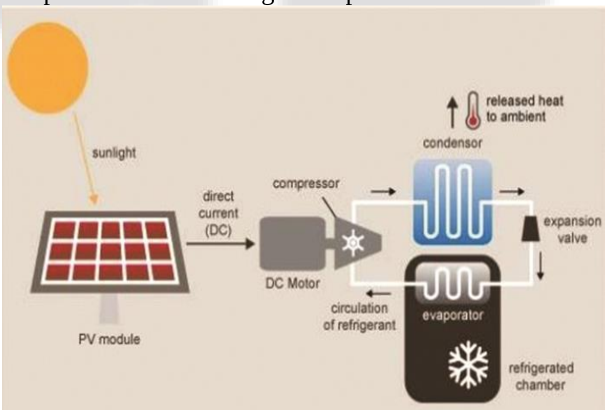

Fig. 1: Photovoltaic operated Cycle

III. APPLICATION OF MCE TO PRODUCE COLD

The magnetic cycles are generally composed of the process of magnetization and demagnetization, in which heat is discharged or absorbed in four steps as depicted by From thermodynamic point of view, the magnetic cooling can be realized by: Carnot, Stirling, Ericsson and Brayton, where the Ericsson and Brayton cycles are believed to be the most suitable for such medium or room temperature cooling. Such cycles are predisposed to yield high cooling efficiency of the magnetic materials. The conventional gas compression process that is driven by continuously repeating the four different basic processes shown. The steps of the magnetic refrigeration process are analogous to those of the conventional refrigeration. One can see that the compression and expansion are replaced by adiabatic magnetization and demagnetization, respectively. These processes change the temperature of the material and heat may be extracted and injected just as in the conventional process.

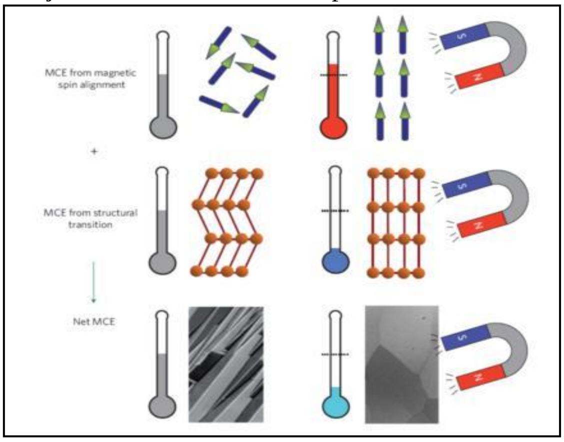

Fig. 2: Variation of Magnetic Field W.R.T Temperature

IV. MAGNETIC REFRIGERATION SYSTEMS

Since the first magnetic refrigeration system manufactured by Brown in 1976, many researchers around the world have paid considerable attention to the magnetic refrigeration around room temperature and consecutively developed some interesting systems. This section reviews in detail some of the magnetic refrigeration systems available until now. A majority of the successful magnetic refrigeration research done to this point was completed by the Ames Laboratory at the University of Iowa and by the Astronautics Corporation of America in Madison, Wisconsin. Karl Gschneidner and Vitalij Pecharsky of the Ames Laboratory and Carl Zimm of the Astronautics Corporation have led this research. The team has developed a working system that uses two beds containing spherical powder of Gadolinium with water being used as the heat transfer fluid. The magnetic field for this system is 5 Tesla, providing a temperature span of 38 K.

The maximum values obtained from this unit include a cooling power of 600 Watts, Coefficients of Performance near 15, and efficiency of approximately 60% of Carnot efficiency.3 Due to the high magnetic field, however, this system is not applicable for use at home.

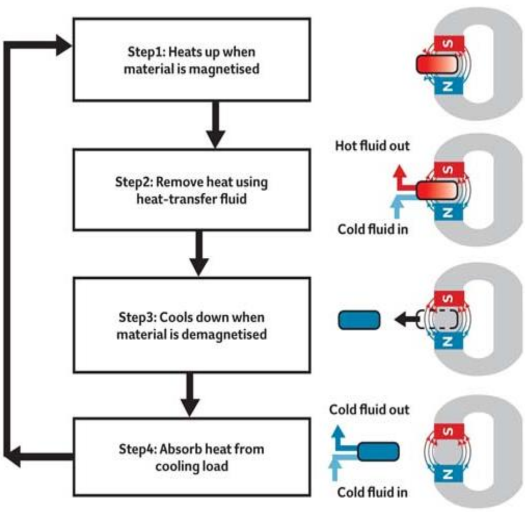

Fig. 3: Magnetic Refrigeration System

A. Magnetic Refrigeration

For magnetic refrigeration ferromagnetic material is used because of its property regarding to the magnetism and in presence of magnetic field. Whenever a ferromagnetic material is placed in sufficiently high magnetic field under adiabatic condition, the magnetic dipole moment of the material becomes reoriented. This causes increase in the temperature of the material in the magnetic field. The temperature raising effect is called magneto caloric effect. When this magnetic field is subsequently removed, the magnetic dipole of the material comes in rest position and the temperature of the ferromagnetic material gets down and shows cooling effect. This cooling effect is called magnetic cooling.

The change of entropy (S) of a magnetic material upon the application of a magnetic field (H) is related to that of magnetization (M) with respect to temperature (T) through the thermodynamic Maxwell relation.

$$\left(\frac{ds}{dH}\right)t = -\left(\frac{dM}{dT}\right)h$$

it is easy to state that a material should have large MCE when (dM/dT)h is large and C(S,H) is small at the same temperature . Because (dM/dT)h peaks the magnetic ordering temperature, a large MCE is often expected close to this magnetic phase transition, and the effect may be further maximized as the change in magnetization with respect to temperature occurs in a narrow temperature interval.

B. The Criteria for Selecting Refrigerants

In terms of the theoretical analyses and the magneto caloric nature of existing materials the criteria for selecting magnetic refrigerants for active magnetic refrigerators are given as follows:

1) The large magnetic entropy change and the large adiabatic temperature change (i.e., the large MCE).
2) The large density of magnetic entropy (it is an important factor contributing to the working efficiency of materials); Ferromagnet with large values of effective magnetron number are selected.
3) The small lattice entropy (i.e., the high Debye temperature), much attention should be paid to magnetic refrigerants for room-temperature magnetic refrigerators.
4) The MCE in the temperature range of 1080K or 4250 K, where the Curie temperature of a material is located in and, the large magnetic entropy change can be obtained in the whole temperature range of the cycle.
5) Nearly zero magnetic hysteresis (it is related to the working efficiency of a magnetic refrigerant material).
6) Very small thermal hysteresis (this is related to the reversibility of the MCE of a magnetic refrigerant material).
7) 7. Small specific heat and large thermal conductivity (these ensure remarkable temperature change and rapid heat exchange).
8) 8. Large electric resistance (i.e., the lowering eddy current heating or the small eddy current loss).
9) 9. High chemical stability and simple sample synthesis route are also required for magnetic refrigerant materials.

C. Magnetocaloric Behavior and Magnetic Transition

Most ferromagnetic materials show a second-order magnetic phase transition. It should be noted that a first order transition is able to concentrate the magneto caloric effect (MCE) in a narrow temperature range, whereas second-order transitions are usually spread over a broad temperature range. In addition, there is large thermal and field hysteresis for any first-order transitions. Furthermore, it is stated that the magnitude of the MCE depends not only on the magnetic moments but also on dM/dT. The larger these values, the higher the magneto caloric effect (MCE). This is the reason why not only rare-earth elements and their compounds have large magneto caloric effect (MCEs), but also 3d-based transition–metal compounds can have large magneto caloric effect (MCEs) in case of a first-order transition. In the case of manganite materials, it is the rapid change of magnetization with respect to temperature in the magnetic-ordering phase transition range that causes a large magnetic entropy change, i.e., the large MCE. Indeed, recently revealed that a first order structural transition in close proximity to the magnetic transition has only little influence on the MCE in doped magnates. This includes some important refrigeration cycles which play’s an important role in magnetic cooling, they are explained well below with all possible logics behind the individual topic**.**

V. DESCRIPTION OF COMPONENTS OF FINAL PRODUCT

The final product is consist of following components:
1) Thermal insulated box.
2) Solar panel.
3) Solar charge controller.
4) Battery.
5) Temperature sensor.

A. Thermal Insulated Box

This thermal insulated box has a capacity of 7.5 liter. This box acts as load in which cooling is takes place. A heat absorber is attached on the outer side of one wall of this thermal insulated box. On this heat absorber a heat sink is attached for further heat transfer to take out heat from the box. A pc fan is attached on the heat sink to increase the heat transfer by forced convection.

B. Solar Panel

Solar panel absorbs the sunlight as a source of energy to generate electricity. A photovoltaic (PV) module is a packaged, connect assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic system that generates and supplies solar electricity in commercial and residential application. Solar panel used in this model has power of 40W capacity to absorb.

Fig. 4: Solar Panel

C. Solar Charge Control

A solar charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk. It may also prevent completely draining a battery, or perform controlled discharges. Solar panel and battery are connected to the solar charge controller. Charge controller balances the electric charge which comes from the solar panel and send it to the load. A battery is used as backup power, solar charge controller draws power from the battery to maintain the power flow to the load.

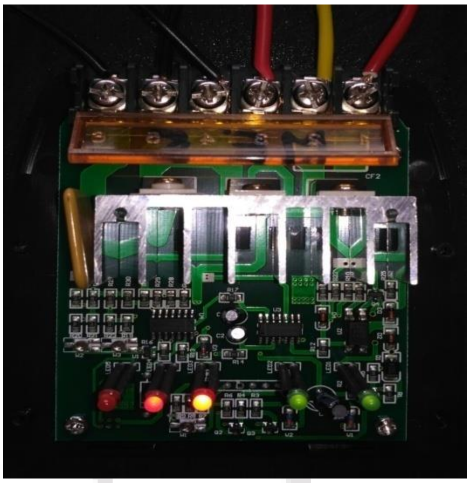

Fig. 5: Solar Charge Controller

D. Battery

A 12 volt battery is used as backup power and it is connected to the solar charge controller through wires. Battery provides power when solar panel does not produces enough power to run the system.

Fig. 6: Battery 12V

E. Temperature sensor

Temperature sensor is used to measure the temperature inside the thermal insulated box. Temperature sensor having a display on which temperature is shown in degree Celsius

Fig. 7: Temperature Sensor

VI. WORKING OF SOLAR POWERED COOLING SYSTEM

This cooling system is consist of a solar panel, thermal insulated box, solar charge controller, a battery and a temperature sensor. Solar panel is connected to the solar charge controller through wires. Sunlight strikes on the solar panel and it generates electricity which is used to run cooling system. Solar charge controller controls the flow of current to the load. Sometimes, sun light does not strikes enough on the solar panel due to clouds or seasons which leads to decrease in production of electricity and it is not enough to run cooling system. To resolve this problem a battery is used as power backup to run the cooling system. This battery is connected to the solar charge controller through wire. Whenever solar panel does not produce enough power to run the cooling system, it automatically draws power from the battery to run the cooling system. Solar charge controller also prevents overflow of power to the load.

Fig. 8: Solar powered cooling system

VII. WORKING OF PELTIER COOLER

The Peltier effect occurs whenever electrical current flows through two dissimilar conductors; depending on the direction of current flow, the junction of the two conductors will either absorb or release heat. In the world of thermoelectric technology, semiconductors (usually Bismuth Telluride) are the material of choice for producing the Peltier effect because they can be more easily optimized for pumping heat. Using this type of material, a Peltier device (i.e., thermoelectric module) can be constructed in its simplest form around a single semiconductor “pellet” which is soldered to electrically-conductive material on each end (usually plated copper). In this configuration, the second dissimilar material required for the Peltier effect, is actually the copper connection paths to the power supply.

VIII. RESULTS AND DISCUSSIONS

The Peltier Cooler market products are designed for small uses because Peltier effect cannot be used for big refrigeration area. We have started our research with the basics of Peltier effect models and found that by changing some design can make it more efficient. We worked on this design and eliminate the heat sink which was on the cooling side of the ceramic plate, we found that it worked quite well in small isolated box. We are not using any type of refrigerant so it is eco-friendly and it does not emit any type of toxic or non-toxic gases, it is a simple cooling system which works on the principle of Thermoelectric cooling.

We decided to make it work with free energy, so we are using a solar panel with it. The solar panel is attached with the charge controller so that we can charge and use the edition power as battery. Charge controller used for taking the charge from solar and battery is attached with it which maintain the flow of current and make work better with smooth flow of current to the load. By this action our Peltier Cooler can be used in those places also where electricity is not available. It works on 12V power input so it is less power consumed and the temperature it reached is $16\text{-}18^0$C from the room temperature. This method is really going to be used wide in urban and rural areas. The price of making this model is less than the other techniques it could be around 4000 Rupees with all the sub equipment like battery and solar panel. It is less cost product which is very efficient and works in any conditions.

IX. APPLICATIONS

There is a demand for cooling in many parts of the world where there is no firm electricity supply and conventional fuels are difficult or expensive to obtain. Requirements tend to be either for medical uses where a high capital cost per kW of cooling is acceptable, or for food (especially fish) preservation where the cooling power required is much greater and the acceptable cost per kW may be lower.

Vaccine storage refrigerators have been sold at a low cost of cooling, the lower cost being for a solar thermal system sold by the French company BLM and the larger for a typical photovoltaic system. These high costs are considered acceptable since the application is related to medical provision. Harvey has shown that in the case of a fish storage ice-maker for Zambia, the required capital and he concluded that a 1 tonne ice/day solar thermal refrigerator could be built to this price. There is little possibility that the higher costs per watt of the smaller units could be justified in larger plant.

X. CONCLUSIONS

An overall system coefficient of performance (COP sys) can be defined as the ratio of refrigeration capacity to input solar energy. The COP sys is low for all three types of solar refrigeration systems. However, this definition of efficiency may not be the most relevant metric for a solar refrigeration system because the fuel that drives the system during operation, solar energy, is free. Other system metrics that are more important are the specific size, weight, and, of course, the cost.

A number of barriers have prevented more widespread use of solar refrigeration systems. First, solar refrigeration systems necessarily are more complicated, costly, and bulky than conventional vapor compression systems because of the necessity to locally generate the power needed to operate the refrigeration cycle. Second, the ability of a solar refrigeration system to function is driven by the availability of solar radiation. Because this energy resource is variable, some form of redundancy or energy storage (electrical or thermal) is required for most applications, which further adds to the system size and cost.

XI. ADVANTAGES

The major advantage of solar refrigeration is that it can be designed to operate independent of a utility grid. Applications exist in which this capability is essential, such as storing medicines in remote areas. Of the three solar refrigeration concepts presented here, the photovoltaic system is most appropriate for small capacity portable systems located in areas not near conventional energy sources (electricity or gas). Absorption and solar mechanical systems are necessarily larger and bulkier and require extensive plumbing as well as electrical connections.

In situations where the cost of thermal energy is high, absorption systems may be viable for larger stationary refrigeration systems. The solar mechanical refrigeration systems would require tracking solar collectors to produce high temperatures at which the heat power cycle efficiency becomes competitive. If the capital cost and efficiency of tracking solar collectors can be significantly reduced, this refrigeration system option could be effective in larger scale refrigeration applications.

XII. FUTURE IMPLEMENTATIONS

In the future, your refrigerator might keep your food cold by using magnet. Not only would it use less power and run quieter than your current fridge, but it also would not contain any hydro flouro carbons, gases which can add tremendously to the greenhouse effect if not properly disposed .Magnetic cooling technique is an emerging technology in the field of the refrigeration and air-conditioning system. This system can be used as an alternate of present vapor compression system which contains toxic refrigerant for humans and our environment. So this magnetic cooling system eliminates the toxic vapor compression system in use and an eco-friendly refrigeration system will come in existence. This magnetic cooling system can be used as refrigerator and air condition.

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