"Use of Magnetic Refrigeration using Solid Refrigerant to Eliminate the Requirement of Compressor for Domestic Application"

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Abstract— Conventionally, in most the refrigerator is the second largest user of electricity (13.7%) right after air conditioner (14.1%). Magnetic refrigeration is based on magneto caloric effect which causes a temperature change when a magneto caloric metal is exposed to a magnetic field. With this technology of magnetic refrigeration we can reduce operating as well as maintenance cost when compared to the compressor-based refrigeration. Thus, the high capital cost of the compressor can be eliminated and in return the cost of electricity to operate the compressor can also be reduced. Hence, Magnetic refrigeration can replace conventional refrigeration efficiently and economically. Thus we can conclude that the magnetic refrigeration technology has upper hand over compressor-based refrigeration when both are compared based on environmental impact, operating cost savings and design technology.

Keywords—*compressor; magnetic refrigeration; magneto caloric effect*

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1. INTRODUCTION

Traditional vapor compression systems have most practical applications; but these systems have environmental and efficiency concerns. The CFC and other dangerous refrigerants are used, and the benefits of improving performance over the vapour compression systems, has forced the searcher community to develop other alternative refrigeration means. Thus, new concepts like thermoelectric ,thermo acustic, adsorption, absorption and magnetic cooling [3] have been developed.

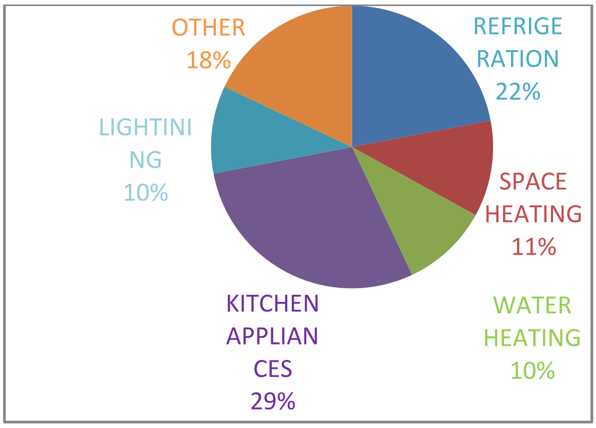

Fig.1 power consumption of various household appliances

Power consumption by refrigerator system is about 22% among the total consumption of energy in household appliance. Compressor used in refrigerator consumes the maximum input power because efficiency of compressor is about 30-40 %. Magnetic refrigeration technology is based on the magneto caloric effect (MCE) and which try to eliminate the compressor which help in energy saving.

2. PROBLEM STATEMENT

Existing system limitation

Refrigeration is critical to our health and the global economy. Modern refrigeration is almost based on a compression/ expansion refrigeration cycle as is a mature, reliable & relatively low cost technology but some liquids used as refrigerants are hazardous chemicals, while other eventually escape into the environment contributing towards ozone layer depletion and global warming. Conventional refrigeration ultimately promotes deleterious trends in the global climate.

Proposed system merits

Magnetic refrigerator has advantages in refrigeration efficiency, reliability, low noise and environmental friendliness. Traditional refrigeration systems like air-conditioning, freezers or other forms which use gases which expand and perform the transfer of heat. Magnetic refrigeration systems do the same job, but with the use of metallic compounds, not gases. Magnetic refrigeration is seen as an environmentally friendly alternative to conventional vapor- cycle refrigeration. Eliminates the need for the most inefficient part of today's refrigerators, the compressor, it should save costs.

3. REFRIGERATION TECHNOLOGY

Refrigeration is the process of removing heat from an enclosed space, or from a substance, and dumping it the surroundings. The primary purpose of refrigeration is lowering the temperature of the enclosed space or substance. Thus, it also maintains the lower temperature of enclosed space. The term cooing referred as the process of decreasing the temperature by which heat is dissipated. Cold is nothing but the absence of heat, hence in order to decrease a temperature, heat removal is required, rather than "adding cold." In order to satisfy the Second Law of Thermodynamics, some form of work must be

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performed. Traditionally this work is done by mechanical work but it can be also be done by magnetism, laser or other means.

Magnetic Refrigeration

Magnetic refrigeration, [1] also known as adiabatic demagnetization, is a technology used for cooling which is based on the magneto caloric effect. It is an intrinsic property of magnetic solids. The refrigerant such as cerium magnesium nitrate is often a paramagnetic salt. Initially, strong magnetic field is applied to the refrigerant, thus, it force various magnetic dipoles to align. Hence, these degrees of freedom of the refrigerant are put into a state of lowered entropy. A heat sink then heat released by the refrigerant due to its entropy loss is absorbed. Thermal contact with the heat sink is then broken so that the system is insulated, further the magnetic field supplied is switched off. This increases the heat capacity of the refrigerant, i.e. it decreases its temperature below the temperature of the heat sink. The operating principle of magnetic refrigeration:-

- To control the entropy of a sample of material, a strong magnetic field is generally used.
- The orientation of magnetic dipoles in the refrigerant is constrained by magnetic fields. If stronger is the magnetic field, the more aligned the dipoles are, corresponding to lower entropy and heat capacity because the internal degrees of freedom of material has lost.
- When the refrigerant is kept at a constant temperature by the thermal contact with a heat sink when the magnetic field is switched on, the refrigerant loses some energy because it is equilibrated with the heat sink.

When magnetic field is switched off ,

- The heat capacity of the refrigerant increases again because the degrees of freedom of the dipoles are once again liberated, pulling their share of equi-partitioned energy from the motion of the molecules, thus it lowers the overall temperature of a system with decrease in energy.
- As the system is insulated when the magnetic field is switched off, the process is adiabatic, i.e., the exchange energy of the system with its surroundings can no longer take place, and its temperature decreases below its initial value, that of the heat sink.

4. WORKING PRINCIPLE

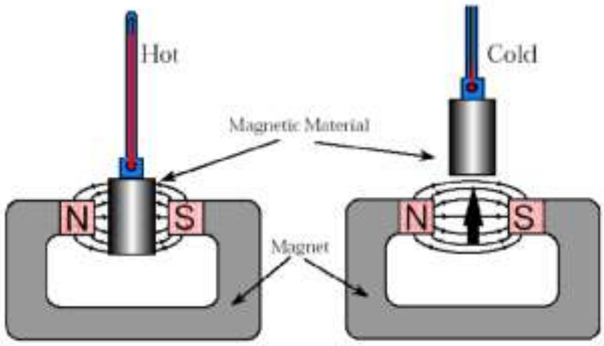

Fig.2 Working principle

When the magnetic material is placed in the magnetic field, the temperature of it increases which can be seen by rise in temperature of the thermometer. But on the other side the thermometer shows decrease in temperature, when the magnetic material is removed from the magnetic field.[2]

A. Working of magnetic refrigeration

Magnetic refrigeration Consists of two beds. Beds consist of spherical powder of Gadolinium with water was used as the heat transfer fluid. The magnetic field applied to this system is 5 Wb/m2. The magnetic refrigeration system is shown in Figure-3. The heat transfer fluid for the system used is a mixture of water and ethanol. The fluid first passes through the hot heat exchanger. In this heat exchanger air is used to transfer heat to the atmosphere. The fluid then passes through the copper plates. These plates are attached to the no magnetized cooler-magneto caloric beds where they lose heat.

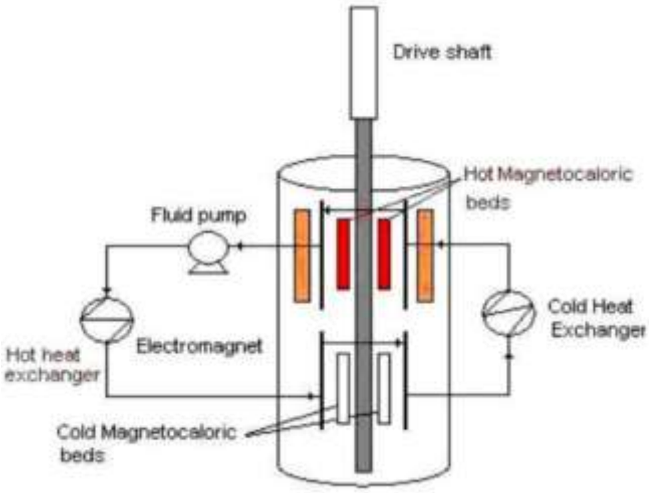

Fig.3 Magnetic refrigeration system

The air is blown over this cold fluid by fan into the freezer to keep the freezer temperature of around 0°F. The heat transfer fluid then gets heated up to 80°F, as it passes through the copper plates which are adjoined by the magnetized warmer magneto caloric beds, where it continues to cycle around the loop.[2] However, the magneto caloric beds move up and

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down simultaneously, into and out of the magnetic field. The second position of the beds is shown in Figure 3. The cold air from the freezer is blown into the refrigerator by the freezer fan. Around 39°F the temperature of the refrigerator section is kept.

5. MAGNETIC REFRIGERATION CYCLE

The magnetic refrigeration is mainly based on magneto caloric effect according to which Some materials change in temperature when they are magnetized and demagnetized. Near the phase transition of the magnetic materials, the adiabatic application of a magnetic field reduces the magnetic entropy by ordering the magnetic moments. This results in a temperature increase of the magnetic material. This phenomenon is practically reversible for some magnetic materials; thus, adiabatic removal of the field revert the magnetic entropy to its original state and cools the material accordingly. Magnetic refrigeration is a potentially more efficient process than gas compression and expansion because of reversibility combined with the ability that makes to create devices with inherent work recovery.

The efficiency of magnetic refrigeration when compared with conventional refrigerators can be as much as 50% greater.

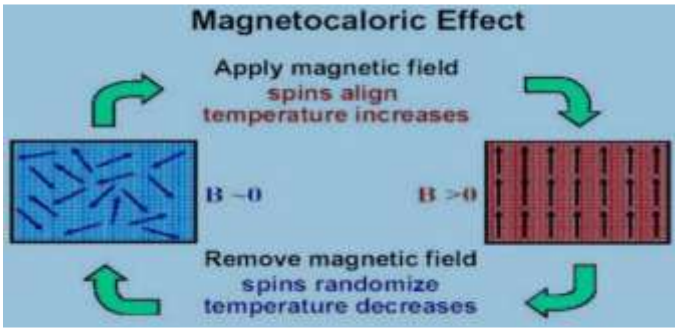

Fig. 4 Effect of magnetic field application

Process is similar to gas compression and expansion cycle as used in conventional refrigeration cycle.

Thermodynamic Cycle:-

- Adiabatic Magnetization
- Isomagnetic Enthalpy Transfer
- Adiabatic demagnetization
- Isomagnetic Entropic Transfer

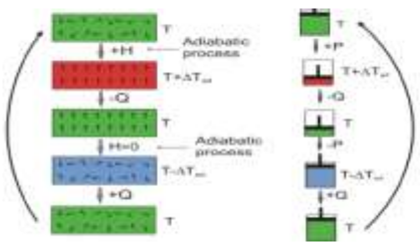

Fig. 5 Magnetic Refrigeration Cycle

A. *Comparison between Magnetic refrigeration and Conventional Refrigeration*

The four basic process s of a conventional gas refrigeration system are compression of a gas, then extraction of heat, Expansion of the gas, and injection of heat. The two process steps extraction of heat and expansion are responsible for a cooling process in two steps. The steps of a magnetic refrigeration process are Analogous. A magneto caloric material is moved into a magnetic field and then Expansion is carried out by moving the material out of the magnetic field. There are differences between the two processes. The heat Injection and rejection is a rather Fast process in a gaseous refrigerant, because turbulent action transports heat very fast. Unfortunately, this is not the case in the solid Magneto caloric materials. Here the transport mechanism for heat is slow molecular diffusion.

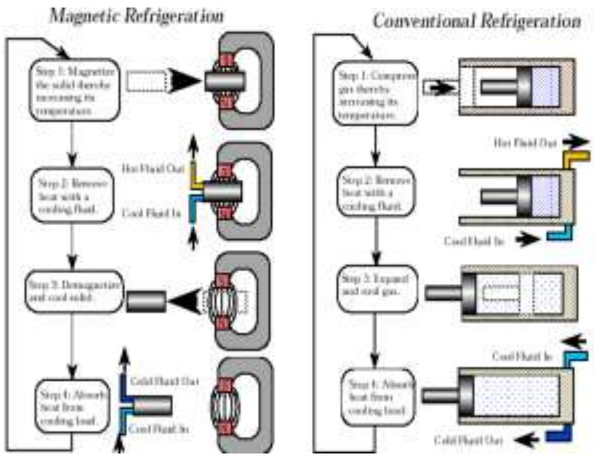

Fig.6 comparison of conventional refrigeration with magnetic refrigeration

Therefore, at present Fi Ligree porous structures are considered to be the best Solution to overcome this problem. The small distances from the central regions of the material to an adjacent fluid Domain, where a heat transport fluid captures the heat and transports it out of the material, are ideal to make the Magnetic cooling process faster.

Furthermore, the not very Large adiabatic temperature differences of magneto caloric Materials will require more often a design of cascade or Regenerative magnetic refrigerators than in conventional Refrigerators and hence require additional heat transfer Steps. In the Figure.6.2 (a) is the conventional gas compression Process is driven by continuously repeating The four different basic processes shown and (b) is the Magnetic refrigeration cycle comparison. Compression is replaced by adiabatic magnetization and expansion by adiabatic demagnetization.

6. CONCLUSION

In conventional refrigeration system most of power is consumed by compressor as its efficiency is low. Thus, with

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the help of magnetic refrigeration technology we can eliminate the use of vapor compression cycle. Hence, operating and maintenance cost is minimize. As compressor is eliminated cost of electricity consumption is also reduced. In conventional refrigeration system refrigerants (CFC) are used leading to green house effects. But in this magnetic refrigeration technology solid refrigerant (Gd) is used making this technology eco-friendly. There are some thermal and magnetic hysteresis problems to be Solved so that the Materials that exhibits the MCE to become really useful. This refrigeration can be used for household refrigerator, central Cooling systems, room air conditioners and Supermarket refrigeration applications.

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