Thermoelectric Device (Heating or Cooling) By Using Solar Energy

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In Today's world global warming is being increasing year by year. There are many reasons like pollution, deforestation, water contamination, etc...In coming years the major problem before us is depletion of ozone layer which is caused by the release of CFC's. Some of the equipment's which causes this effect is refrigerators, AC's. In this project we are mainly focusing on a solution to control this problem we have focused on refrigerators which releases CFC's. Here we are designing a mini solar based refrigerator which is cheaper as well as eco friendly. Here we are using Micro controller (AT89S52) allows dynamic and faster control. Liquid crystal display (LCD) makes the system user friendly. In this project we are using solar panels for charging a Lead Acid Battery (12V, 1.2 Amp), a pelteir thermoelectric device which when connected to battery generates cooling effect on one side and heat is dissipated on other side through heat sink, a cooling fan is used for dissipating the heat from the heat sink. By changing the terminals of battery heating effect can be produced. The Cop of this device is always less than 1 because here we use low grade thermal energy which is directly absorbed form sunlight. Cop is mainly depends upon the efficiency of solar panel. The amount of radiation incident upon the solar panel and the exergy generated is comparatively low for a given surface area of solar panel.This project uses regulated 5V; 500mA power supply. A 7805 three terminal voltage regulator is used for voltage regulation. Bridge type full wave rectifier is used to rectify the ac output of secondary of 230/12V step down transformer.

Methods of refrigeration:

Methods of refrigeration can be classified as non-cyclic, cyclic and thermoelectric.

Non-cyclic refrigeration:

In non-cyclic refrigeration, cooling is accomplished by melting ice or by subliming dry ice (frozen carbon dioxide).These methods are used for small-scale refrigeration such as in laboratories and workshops, or in portable coolers.

Cyclic refrigeration:

This consists of a refrigeration cycle, where heat is removed from a low-temperature space or source and rejected to a high-temperature sink with the help of external work, and its inverse, the thermodynamic power cycle. In the power cycle, heat is supplied from a high-temperature source to the engine, part of the heat being used to produce work and the rest being rejected to a low temperature sink. This satisfies the second law of thermodynamics. Cyclic refrigeration can be classified as:

1. Vapor cycle, and
2 Gas cycle

Vapor cycle refrigeration can further be classified as:

a) Vapour-compression refrigeration
b) Vapour-absorption refrigeration

Vapour-compression cycle:

The vapor-compression cycle is used in most household refrigerators as well as in many large commercial and industrial refrigeration systems. Figure 1 provides a schematic diagram of the components of a typical vapor-compression refrigeration system. Figure 2 provides detailed process with T-s diagram.

Vapor-Compression Cycle Components
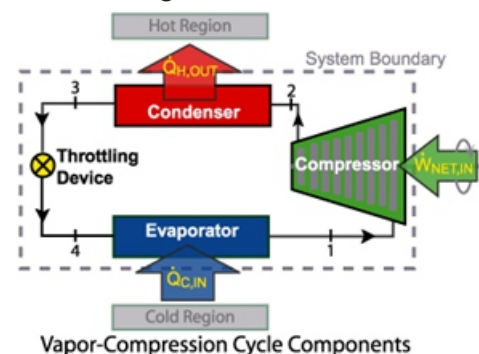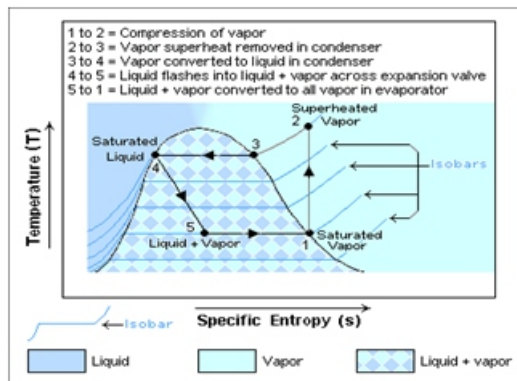
Vapour absorption cycle:

In the early years of the twentieth century, the vapor absorption cycle using water-ammonia systems was popular and widely used. After the development of the vapor compression cycle, the vapor absorption cycle lost much of its importance because of its low coefficient of performance (about one fifth of that of the vapor compression cycle). The absorption cycle is similar to the compression cycle, except for the method of raising the pressure of the refrigerant vapor. In the absorption system, the compressor is replaced by an absorber which dissolves the refrigerant in a suitable liquid, a liquid pump which raises the pressure and a generator which, on heat addition, drives off the refrigerant vapor from the high pressure liquid. Some work is required by the liquid pump but, for a given quantity of refrigerant, it is much smaller than needed by the compressor in the vapor compression cycle. In an absorption refrigerator, a suitable combination of refrigerant and absorbent is used. The most common combinations are ammonia (refrigerant) and water (absorbent), and water (refrigerant) and lithium bromide (absorbent).

Gas cycle:

When the working fluid is a gas that is compressed and expanded but doesn't change phase, the refrigeration cycle is called a gas cycle. Air is most often this working fluid. As there is no condensation and evaporation intended in a gas cycle, components corresponding to the condenser and evaporator in a vapor compression cycle are the hot and cold gas-to-gas heat exchangers in gas cycles. The gas cycle is less efficient than the vapor compression cycle because the gas cycle works on the reverse Brayton cycle instead of the reverse Rankine cycle. Because of their lower efficiency and larger bulk, air cycle coolers are not often used nowadays in terrestrial cooling devices.

The air cycle machine is very common, however, on gas turbine powered jet aircraft because compressed air is readily available from the engines' compressor sections. These jet aircraft's cooling and ventilation units also serve the purpose of pressurizing the aircraft.

Thermoelectric refrigeration:

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments.

Magnetic refrigeration:

Magnetic refrigeration, or adiabatic demagnetization, is a cooling technology based on the magneto caloric effect, an intrinsic property of magnetic solids. The refrigerant is often a paramagnetic salt, such as cerium magnesium nitrate. The active magnetic dipoles in this case are those of the electron shells of the paramagnetic atoms. A strong magnetic field is applied to the refrigerant, forcing its various magnetic dipoles to align and putting these degrees of freedom of the refrigerant into a state of lowered entropy.

Other methods:

Other methods of refrigeration include the air cycle machine used in aircraft; the vortex tube used for spot cooling, when compressed air is available; and thermo acoustic refrigeration using sound waves in a pressurized gas to drive heat transfer and heat exchange. Many Stirling cycle heat engines can be run backwards to act as a refrigerator, and therefore these engines have a niche use in cryogenics.

Thermoelectric effect:

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates a voltage when there is a different temperature on each side. Conversely when a voltage is applied to it, it creates a temperature difference (known as the Peltier effect).

Seebeck effect:

The Seebeck effect is the conversion of temperature differences directly into electricity.

$$V = \int_{T_1}^{T_2} \left(S_B(T) - S_A(T) \right) dT.$$
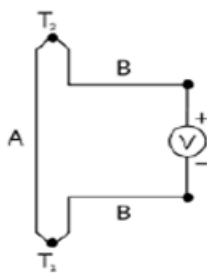

Fig -Seeback Effect

SA and SB are the Seebeck coefficients (also called thermoelectric power or thermo power) of the metals A and B as a function of temperature, and T1 and T2 are the temperatures of the two junctions.The Seebeck effect is commonly used in a device called a thermocouple (because it is made from a coupling or junction of materials, usually metals) to measure a temperature difference directly or to measure an absolute temperature by setting one end to a known temperature. A metal of unknown composition can be classified by its thermoelectric effect if a metallic probe of known composition, kept at a constant temperature, is held in contact with it. Industrial quality control instruments use this Seebeck effect to identify metal alloys. This is known as thermoelectric alloy sorting.The Seebeck effect is due to two effects: charge carrier diffusion and phonon drag (described below). If both connections are held at the same temperature, but one connection is periodically opened and closed, an AC voltage is measured, which is also temperature dependent.

Peltier effect:

Thermoelectric cooling devices utilize the Peltier effect, whereby the passage of a direct electric current through the junction of two dissimilar conducting materials causes the junction to either cool down (absorbing heat) or warm up (rejecting heat), depending on the direction of the current.
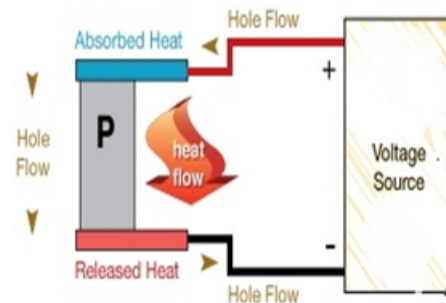

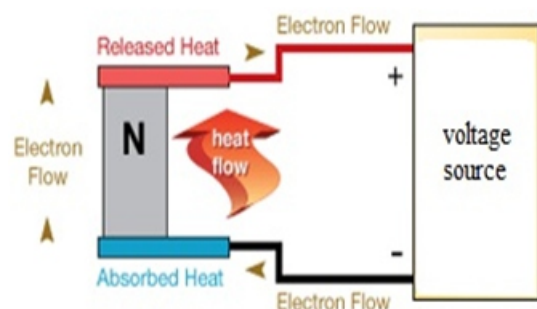
Fig P-Type material connection

Fig N-Type material connection

Fig shows a pair of adjacent thermo element legs joined at one end by a conducting metal strip forming a junction between the legs. Thus, the legs are connected in series electrically but act in parallel thermally. This unit is referred to as a thermoelectric couple and is the basic building block of a thermoelectric (or Peltier) cooling module.

Thermo power:

The thermo power, thermoelectric power, or Seebeck coefficient of a material measures the magnitude of an induced thermoelectric voltage in response to a temperature difference across that material. The thermo power has units of (V/K), though in practice it is more common to use microvolts per Kelvin. Values in the hundreds of µV/K, negative or positive, are typical of good thermoelectric materials. The term thermo power is a misnomer since it measures the voltage or electric field induced in response to a temperature difference, not the electric power. An applied temperature difference causes charged carriers in the material, whether they are electrons or holes, to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated. Mobile charged carriers migrating to the cold side leave behind their oppositely charged and immobile nuclei at the hot side thus giving rise to a thermoelectric voltage (thermoelectric

refers to the fact that the voltage is created by a temperature difference).

Charge-carrier diffusion:

Charge carriers in the materials (electrons in metals, electrons and holes in semiconductors, ions in ionic conductors) will diffuse when one end of a conductor is at a different temperature to the other. Hot carriers diffuse from the hot end to the cold end, since there is a lower density of hot carriers at the cold end of the conductor. Cold carriers diffuse from the cold end to the hot end for the same reason.
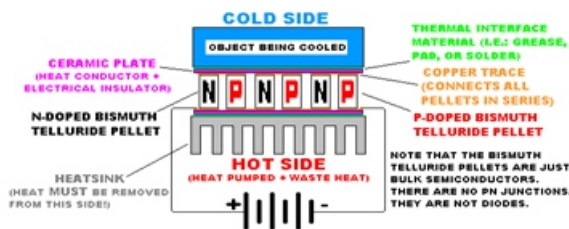

Fig while current in Forward Bias

The Peltier effect bears the name of Jean-Charles Peltier, a French physicist who in 1834 discovered the calorific effect of an electric current at the junction of two different metals. When a current is made to flow through the circuit, heat is evolved at the upper junction (at T2), and absorbed at the lower junction (at T1). The Peltier heat absorbed by the lower junction per unit time, is equal to

$$Q = \pi ABI = (\pi B - \pi A)I$$

where π is the Peltier coefficient ΠAB of the entire thermocouple, and ΠA and ΠB are the coefficients of each material. P-type silicon typically has a positive Peltier coefficient (though not above ~550 K), and n-type silicon is typically negative. The Peltier coefficients represent how much heat current is carried per unit charge through a given material. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if ΠA and ΠB are different. The ratio of the V and T defines the Seebeck coefficient of the thermoelectric couple, $\alpha np = V/T$, which has units of V/K. The Peltier and Seebeck coefficients of a thermoelectric couple are related by

$$\pi np = \alpha np T$$

where T is the absolute temperature of the junction

Solar panel:

A solar panel is a device that collects photons of sunlight, which are very small packets of electromagnetic radiation energy, and converts them into electrical current that can be used to power electrical loads. Using solar panels is a very practical way to produce electricity for many applications.
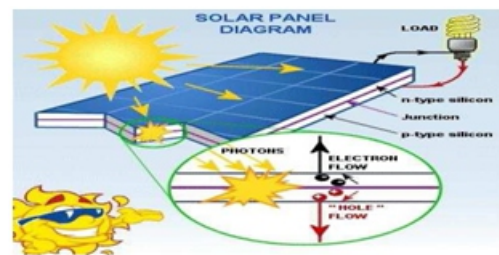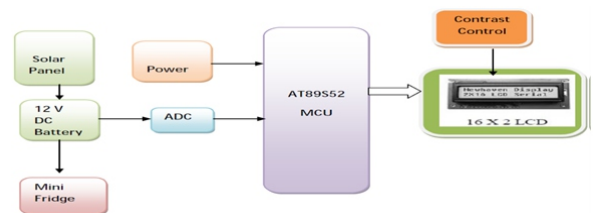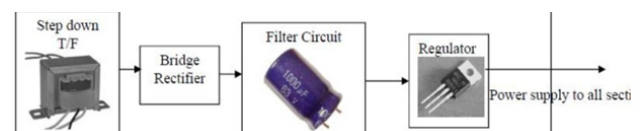

Fig Solar panel function

POWER SUPPLY

WORKING PROCEDURE:

» Here we are using Micro controller (AT89S52) allows dynamic and faster control.
» Liquid crystal display (LCD) makes the system user-friendly.
» In this project we are using solar panels for charging a Lead Acid Battery (12V, 1.2 Amp hrs), a peltier thermoelectric device which when connected to battery generates cooling effect on one side and heat is dissipated on other side through heat sink, a cooling fan is used for dissipating the heat from the heat sink.
» ADC is used to convert the analogy signal to digital signals from battery to microcontroller.

A regulator 7803 is used to drive the internal cooling fan and LED

Rate of heat absorption from the cold source, Qc:

In the absence of heat conduction from the hot junctions and ohmic heating of the thermo elements, Q would simply equal the Peltier cooling effect at the cold junction given by πnp .Taking account of these two irreversible effects, which act in opposition to the Peltier heat pumping, and using Equation can be shown that the actual rate of heat absorption by a single thermoelectric couple.

$$Qc = \alpha npTcI - K(Th-Tc) - 0.5I^2R$$

where R is the electrical resistance of the thermo element pair in series and K is the thermal conductance of the thermo element pair in parallel.

Coefficient of performance, COP:

This is equal to the rate of heat absorption divided by the electrical power input We consumed in ohmic heating of the thermo elements and balancing the Seebeck effect generated by the temperature difference T = (Th – Tc) between the junctions. Hence, in general COP is given by COP=QC/Win

Calculations:
Peltier plate type: TEC1-12726 (127 thermocouples & 26 A).

Doping material :

Bismuth Telluride N-Type doping (Bi_2Te_3)
Bismuth Telluride P-Type doping (Bi_2Te_3)
Thermal resistance: 0.4Ω
Input Voltage from Battery: 12 V
Thermal Conductivity (K): 2.8 Wm-1 k-1 .
Input power (P): P = VI
$\qquad 12\times20 = 240W$
$\qquad \alpha np = 95\times10^{-3}$ V/K
Heat Absorption (Q):Q = $\alpha np\times Tc\times I-(K\times\Delta T)$- 0.5 I^2R
$\qquad 95\times 10^{-3}\times20^2\times20$ –
$(2.8\times60) – (0.4\times20\times0.5) = 135$ W
Cofficient of performance (COP):   Q/P
$\qquad 135/240 = 0.56$

APPLICATIONS:

» Solar-powered refrigerators are most commonly used in the developing world to help mitigate poverty and climate change.
» By harnessing solar energy, these refrigerators are able to keep perishable goods such as meat and dairy cool in hot climates, and are used to keep much needed vaccines at their appropriate temperature to avoid spoilage.
» The portable devices can be constructed with simple components and are perfect for areas of the developing world where electricity is unreliable or non-existent.
» Other solar-powered refrigerators were already being employed in areas of Africa which vary in size and technology, as well as their impacts on the environment.
» Batteries (electric refrigerators) or phase-change material is added to provide constant refrigeration.
» The portable solar fridge is used in areas of Africa such as Zambia, Namibia, and South Africa in areas where electricity is often not readily accessible to help preserve perishable foods such as meat and dairy, however, is not yet being used for vaccines.

» CONCLUSION:
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Thermoelectric systems are solid-state heat devices that either convert heat directly into electricity or transform electric power into thermal power for heating or cooling.

The operation principles are the Seebeck and Peltier effects and the devices offer several advantages over other technologies. Each application will have its own set of requirements that likely will vary in level of importance. Nowadays the applications are restricted to small thermal systems but the trend in recent years has been for larger thermoelectric systems. So, the thermoelectricity is one important field for the development of environmentally friendly thermal systems and the researches of new thermoelectric materials with large Seebeck coefficient and appropriate technology could make a breakthrough in the applications of thermoelectric devices in many applications.

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