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Fabrication of Smart Mini Thermoelectric Peltier Refrigerator

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ABSTRACT: The outcome of the increased momentum in the progress on technology and science has created tons of varieties of system that can be used to create the effect of refrigeration. Such instrument that uses thermoelectric cooling is also called a Peltier heat pump or solid state refrigerator. It is mainly used in cooling systems although heating can also be achieved. It can act as a temperature controller that either heats or cool. The main advantage is that it is a solid state device and hence maintenance free. Thermoelectric refrigeration is a new alternative as it reduceselectricity consumption to produce cooling effect and also satisfies today's energy challenges. Hence, the need for smartthermoelectric refrigeration in developing countries is very high where long life and low maintenance are needed. The purpose of this study is to fabricate a working smart thermoelectric Peltierrefrigerator to cool a volume of 4L that utilizes the Peltier effect to cool and maintain a selected temperature range of 3°C to 23°C. The design meets the purpose to cool this volume to required temperature within a short time and provide retention of at least 30 minutes. The design and fabrication of smart mini thermoelectric refrigerator are presented.

I. INTRODUCTION

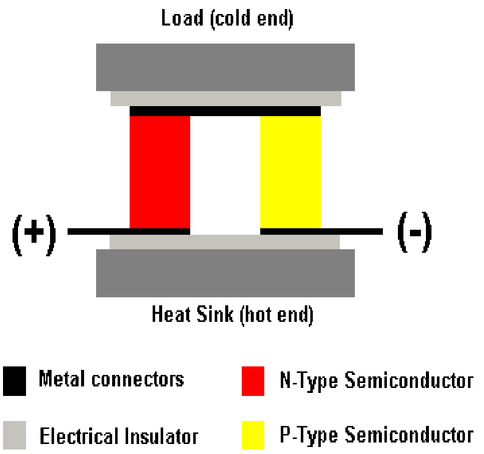
Modern cooling systems such as those used in refrigerators utilize a compressor and a working fluid to transfer heat. Heat energy is absorbed and dissipated as the working fluid undergoes expansion and compression and changes phase from liquid to vapor and back, respectively. Semi-conductor thermoelectric coolers (also known as Peltier coolers) offer multiple advantages over conventional systems. They are entirely solid state devices, with no moving parts; this makes them rigid, reliable, and quiet. They use no ozonedepleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to conventional refrigeration. They can be extremely small, much more than that of compressor-based systems. Precise temperature control (< ± 0.1 °C) can be achieved with Peltier coolers. However, their efficiency is low compared to the standard refrigerators. Thus, they are used in ideal applicationswhere their unique advantages priorities their lowefficiency. Even though some large-scale applications have been considered (on submarines and surface vehicles), Peltier coolers are generally used where small size is needed and the cooling demands are not much large, such as for cooling electronic circuit components.

II. THERMORLRCTRIC COOLING MODULES

Early 19th century scientists, Thomas Seebeck and Jean Peltier, first discovered the incident that are the base of Peltier cooling;they found that if we place a temperature gradient across the junctions of two different conductors, electrical current would flow. Peltier, on the other side, found that passing current through two different electrical conductors, forced heat to be either dissipated or absorbed at the junction of the two materials. It was only after 1950s, the advancements in semiconductor technology, however, those practical applications for thermoelectric devices became feasible. With modern equipment, we can now produce thermoelectric efficient solid-state heat-pumping for both heating and cooling purpose; several of these units can also be used to generate DC power at minimized efficiency. New and often elegant uses for thermo-electrics continue to be developed on a daily basis.

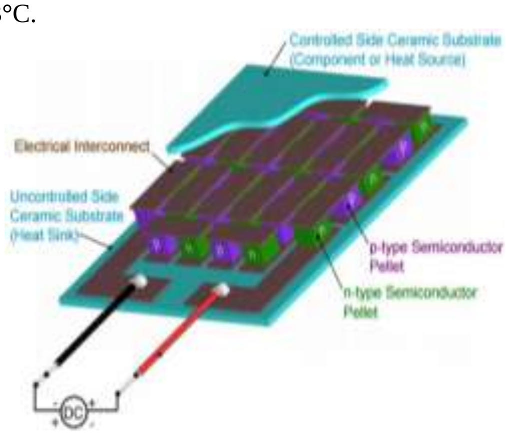
A general thermoelectric module consists of amatrix of Bismuth Telluride semiconductor pellets that have been carrier (either positive or negative–) carries the majority of current. The pairs of N/P pellets are aligned and configured so that they are connected electrically in series, but thermally in parallel. Ceramic substrates with metallic coating provide the platform for the pellets and the small conductive tabs that connect them.

When DC voltage is applied to the thermoelectric module, the positive and negative charge carriers in the pellet matrix absorb heat energy from one substrate surface and dissipate it to the substrate at the contradictory side. The surface where heat energy is absorbed becomes cold; while the contradictory surface where heat energy is dissipated becomes hot. Reversing the direction of flow of electric currentresults in the reversed hot and cold plate sides.



III. DESIGN OF THERMO ELECTRIC REFRIGERATOR

In this current work, the superior aim is to develop a refrigeration cooling system with a 4L capacity of cooling chamber. It is required to fabricate a system which is capable of maintaining the temperature of the materials between 3°C to 23°C.



Thermoelectric cooling uses the Peltier effect to generatea heat flux between the junctions of two dissimilar materials. A Peltier cooler, heater or thermoelectric heat pump is a solid-state device that works like an active heat pump which transfers heat from one side of the device to the other, with less consumption of electrical energy, which in the end dependson the direction of current flow assembly.

1.1. GEOMETRY

With the measurements imposed by the aim, a double-walled rectangular box with an EPS insulation sandwiched in between the walls is selected and having the following dimensions:

Top and bottom panel = 0.35 x 0.35m

Vertical side panel = 0.35 x 0.35m

1.2. Front and back panel = 0.35 x 0.35 m

MATERIALS

Mild steel sheets with thermal conductivity (K) of 50W/mKwere used as outer walls of refrigerator. Expanded polystyrene (EPS) slabs with a thickness of 5cm, having a density of 30kg per metercube and thermal conductivity (K) of 0.34W/mK were used to give the required thermal insulation of the refrigerator body. Typical valueranges from 0.033to 0.039 W/mK depending on the density of the EPS board. The value of 0.038 W/m-K was obtained at 15 kg per meter cubeon the other hand the value of 0.033 W/mK was obtained at 40kg per meter cube.

1.3. DESIGN PROCEDURE

In fabricating a smart thermoelectric refrigeration system, one of the most critical tasks is to understand the mechanism of thermal load. With this huge information, we can qualify to choose the best thermoelectric device or heat exchangers for the heat transfer. Every thermoelectric cooling system has itsunique capacity for dissipating heat. In order to achieve the professional objectives, the approximate of the amount of heat that must be released from the thermal load is calculated. Once the correct thermoelectric module is selected, thermo-siphon system for heat release from the hot side of the module is designed on the basis of amount of heat that has to be dissipated to cool the other side.

1.4. HEAT LOAD CALCULATION

The two main parts of thermal load in thermoelectric cooling systems are the active loads and passive loads.

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Active load comes under play whenever a part of the load actually dissipates heat. For example in an electronic circuit the circuit components would dissipate power depending upon its voltage and current requirements (P =V*I). Severalthermoelectricapplications don't have an active load and this term can be completelyabandoned in these cases. To maintain a particular temperature variance between the thermal load of the system and the apparent outerenvironment, a small amount of energy must continually flow into or out of the load cells. The rate of the flow of this energy is termed as passive energy.With a thermoelectric system, the main motive is to keep the thermal load at a lower temperature than the ambient environment temperature. But unluckily, no matter how perfect the design of the system is, there will always be some leakage of energy in the system. It is impossible to create an insulation material with infinite thermal resistance, so some heat passes right through the surface of the load cell.Even the sealants used to deal with the unavoidable holes will also be imperfect. Thus, in a cooling application, some thermal energy leakage into the thermal load will happen from the ambient outer environment.

Temperature to maintain inside the chamber = 10°C Outside temperature or ambient temperature = 30°C Temperature difference between the cabin walls =
30°C – 10 = 20°C KMS = 52 W/mK

IV. FABRICATION AND ASSEMBLY

4.1.THERMOELECCTRIC MODULE

Thermoelectric module (Peltier module) is solidstate heat pumps that operate on the Peltier effect. Peltier effect is the heat emitting or absorbing between two materials when electric current passes across junction. Heat pump is a thermoelectric mechanism, which transfers heat from low temperature body and gives out the same to high temperature body.

4.2. HEAT SINK

The heat sink is a heat exchanger device that dissipates heat from the heating device to the surrounding.The effectiveness of the heat sink plate has a noteworthyimpact on the heat driving capability of the thermoelectric module. The hot side of the module must align with an efficient heatsink of large surface area to readily dissipate large amount of heat.

4.3. HEAT SINK FAN

Several times the heat sink itself become hot during the heat transfer, to get over this problem, an electric device called heat sink fan is used. It is mounted just over the heat sink. Water is used for taking readings and calculations. In these calculations, the properties of water are (density = 1 kg/L and specific heat = 4187 Joules/kg, V = 2.0 L). Coefficient of performance of the refrigerator was then calculated.

4.4. TEMPERATURE INDICATOR

The temperature indicator is a device used to determine the temperature inside the refrigerator. It has a thin cylindrical probe which is put inside the refrigerator cabinwhich senses the temperature inside it and gives the temperature data to the microcontroller device and hence to output display. This device can be connected with Arduino (programmable circuit) device that will then control the temperature of this mini thermoelectric Peltier refrigerator accordingly.

4.5. ARDUINO TEMPERATURE CONTROLLER

A temperature controller as it says is an instrument that is used to control temperature. This temperature controller takes an input from the temperature sensor, processes it in microcontroller, here Arduino UNO and gives an output to the control element that has a heater or a fan connected to it, here thermoelectric module.

To precisely control and process temperature without involving extensive operator, a temperature control system relies upon Arduino UNO microcontroller, which accepts input from a temperature sensor such as LM35 (temperature sensor). It verifies the current temperature to the user input temperature, or limit-point, and provides an output to the control element.For heating control, the output is on when the temperature is below the limit-point, and off above set-point. Since the temperature crosses the limit-point to change the output state, the process temperature will be cycling continually, going from lowerlimit-point to upper, and back to lower until further user input.

Circuit is constructed using ArduinoUNO and LM35 proportional temperature sensor and some other electronic components. In this circuit we will use a low-cost 16*2 LCD module to display current temperature and set limit points. LM35 sensor gives an analog output to ArduinoUNO analog input pin, here A0, which is then compared with limit points, if it is more than limit point, it means the temperature is more than required, the relay turns on and cooling starts and if it is less than limit point, it means the temperature is less than required, another relay turns on and heating starts.

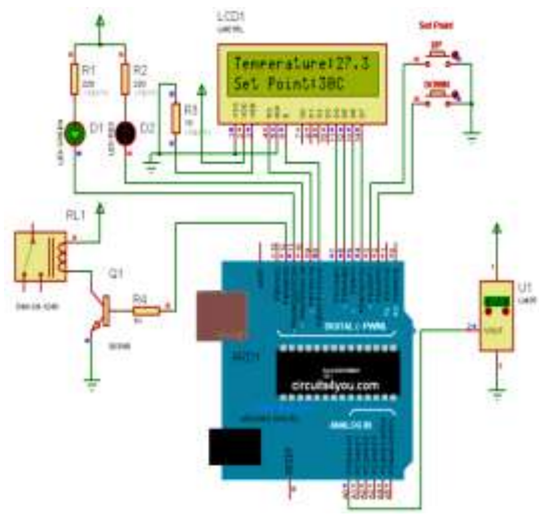

Fig. Circuit diagram showing the connections

V. MODEL OF THEREFRIGERATOR

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Fig. 3D Model of our fabricated refrigerator

VI. CONCLUSION

This is completely eco-friendly, multipurpose and portable project, as the thermoelectric cooling unit is small in size, inaudible,contains no fluids, have no mechanical moving parts and is durable.The COP, coefficient of performance of this thermoelectricrefrigerator is comparatively small than that of a standardcompressor-type refrigerator, where the required cooling capacity is high enough.

We have been prosperous in designing and fabricating a system that fulfills the proposed aim of the project. Although this system has some limitations, so the current design can only be used for light heat loads to lower its temperature to a particularsmall range of temperature. Voluminous modifications need to be embraced before this product can be released for efficient multipurpose use.

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