DESIGN AND FABRICATION OF THRMOELECTRIC REFRIGERATOR

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***Abstract*: A water cooling system based on Peltier Effect has many benefits as being small in size, portable, noiseless, environmental friendly and economical compared to conventional cooling systems. This research focuses on the thermal performance experimental study of a portable thermoelectric water cooling system. During this study, the applied voltage on TE was change to determine its effect on thermal performance. When the applied voltage increases, the hot side temperature increasing, while on the contrary of that appear on the cold side. This increasing the heat absorbed by the cold side as well as the heat rejected from the hot side, while the coefficient of performance decreasing with increasing applied voltage. The thermal resistance of heat sink is inversely proportional to the applied voltage. The increasing of heat sink fan speed has improved the system performance, where it led to an increasing in heat absorbed by the cold side and the heat rejected from the hot side. Initial water temperature has a significant effect on the performance of TE water cooling system. The coefficient of performance equal to 0.14 when using initial water temperature of 15℃, while, it increase to be 0.5 when the initial water temperature increases to 30 ℃. That is happened due to the decrease in temperature gradient between cold side and hot side.**

***Index Terms*: Thermoelectric cooler, TEC, Peltier Effect, Battery, heat sink.**

I. INTRODUCTION

Thermoelectric is the science associated with two essential forms of energy the thermal energy, and the electrical energy. Physically, the thermoelectric effect is the conversion of the thermal energy to electrical energy and vice versa due to the reversibility of the thermoelectric process. In the mode of the cooling or heating, a thermoelectric device (TED) converts the electrical energy represented in the input current into a temperature difference on its hot and cold sides. While in the mode of power generating, TED converts the thermal energy (manifested as the temperature difference across the device) into electrical energy. Thermoelectric devices have become highly attractive because of their solid-state mechanism that does not require any moving parts or working fluids, which decreases mechanical failure. Another advantage of TEDs is that they allow quite cooling/heating and power generating operations unlike the conventional compressor based refrigerator and fuel-based electric generating systems. Such advantages make TEDs on demand in multiple of applications. . (TECs) are highly involved in heating, ventilations and cooling systems (HVAC) and electronic cooling. TECs also can be seen in many other applications such as in sensitive equipment as medical tools and microprocessors due to their high manufacturability and reliability in the temperature controlling and stabilizing. Thermoelectric generators (TEGs) also have various applications such as converting the thermal energy in the exhaust waste into electrical energy in automobile and low-grade applications. Also, in solar energy, TEGs converts the thermal energy from the sunlight into electricity that can be used in many other areas thermoelectric (TE) cooler, sometimes called a thermoelectric module or Pettier cooler, is a semiconductor-based electronic component that functions as a small heat pump. By applying a low voltage DC power source to a TE module, heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face simultaneously is heated. If a typical single-stage thermoelectric module was placed on a heat sink that was maintained at room temperature and the module was then connected to a suitable battery or other DC power source, the "cold" side of the module would cool down. At this point, the module would be pumping almost no heat and would have reached its maximum rated "Delta T (DT)." If heat was gradually added to the module's cold side, the cold side temperature would increase progressively until it eventually equalled the heat sink temperature. At this point the TE cooler would have attained its maximum rated "heat pumping capacity" (Q max). The See beck, Pettier, and Thomson Effects, together with several other phenomena, form the basis of functional thermoelectric modules.

Concept:-

A thermoelectric pair consists of a p-type semiconductor, n-type semiconductor, and copper to connect the semiconductors. A module however, consists of a number of thermoelectric pairs depending on the application. The most widely used semiconductor is Bismuth Telluride. In the recent past however, materials better than Bismuth Telluride have been discovered. Materials like skutterudite have proven to give better results under certain conditions. Depending on whether the module is a thermoelectric cooler or a generator, electric current is either supplied or generated from the system. In a thermoelectric cooler, the main focus of the current work, when an electric current is supplied to the n-type semiconductor, heat is absorbed and hence transported to the hot side. Thereby given an overall cooling effect. When current is applied in the opposite direction, an opposite effect is seen and the module gives a heating effect. This concept holds an advantage of application over commercial refrigerators and heat pumps where these possess the advantage of direct energy conversion, high reliability, low maintenance, no refrigerants and all these advantages stand true mainly because the thermoelectric cooler is a solid state device.

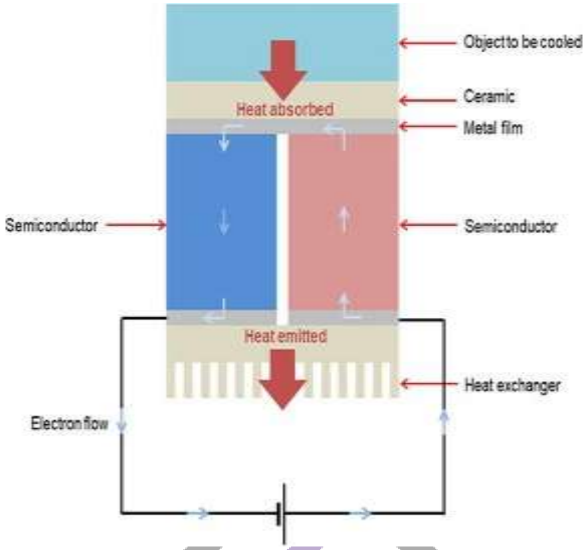

Figure 1: Diagrammatic Representation of a Single Stage Thermoelectric Cooler

II. **LITERATURE SURVEY**:-

The three qualities of interest noted in evaluating thermoelectric cooling performance were: the coefficient of performance, the heat pumping rate, and the maximum temperature difference that the device will produce. All assumptions made in carrying out the analysis of the thermoelectric generator were assumed to hold for the thermoelectric cooler.
Manoj Kumar presented an experimental study of noval potential green refrigeration and air-conditioning technology. They are analyzing the cause and effect of an existing air-conditions system. Thermoelectric cooling provides a promising alternative R&AC technology due to their distinct advantages. The available literature shows that thermoelectric cooling systems are generally only around 5-15% as efficient compared to 4060% achieved by the conventional compression cooling system.

Astrain, Vian& Dominguez conducted an experimental investigation of the COP in the thermoelectric refrigeration by the optimization of heat dissipation. In thermoelectric refrigeration based on the principle of a thermo syphon with phase change is presented. In the experimental optimization phase, a prototype of thermos syphon with a thermal resistance of 0.1 10 K/W has been developed, dissipating the heat of a Peltier pellet with the size of 40*40*3.9 cm, Experimentally proved that the use of thermos syphon with phase change increases the coefficient of performance up to 32%.

Matthieu Cosnier presented an experimental and numerical study of a thermoelectric air-cooling and air-heating system. They have reached a cooling power of 50W per module, with a COP between 1.5 and 2, by supplying an electrical intensity of 4A and maintaining the 5°C temperature difference between the hot and cold sides.

Suwit Jugsujind conducted a study on analyzing thermoelectric refrigerator performance. The refrigeration system of thermoelectric refrigerator (TER; 25 × 25 × 35 cm3) was fabricated by using a thermoelectric cooler (TEC; 4 × 4 cm2) and applied electrical power of 40 W. The TER was decreased from 30 ºC to 20 ºC for 1 hr and slowly decreasing temperature for 24 hrs. The maximum COP of TEC and TER were 3.0 and 0.65.

Wei He Conducted Numerical study of Theoretical and experimental investigation of a thermoelectric cooling and heating system driven by solar. In summer, the thermoelectric device works as a Peltier cooler when electrical power supplied by PV/T modules is applied on it. The minimum temperature 17 degree C is achieved, with COP of the thermoelectric device higher than 0.45.Then compared simulation result and experimental data.

III. **COMPONENTS USED FOR FABRICATION**

1. Peltier modules
Peltier modules are electronic devices designed for cooling objects to below the ambient temperature or maintaining objects at a specific temperature by controlled heating or cooling. Thermoelectric cooling has quickly become a practical proposition for many types of electronic equipment. Devices on the market today are compact, efficient and – with the benefit of advanced internal construction – overcome the traditional reliability challenges that have restricted opportunities for this type of device in the past.

2. Battery 12 v
A twelve-volt battery has six single cells in series producing a fully charged output voltage of 12.6 volts. A typical 12-volt battery used in a RV or marine craft has a rating 125 AH, which means it can supply 10 amps of current for 12.5 hours or 20-amps of

current for a period of 6.25 hours. Each cell is made up of a set of positive and negative plates immersed in a dilute sulfuric acid solution known as electrolyte, and each cell has a voltage of around 2.1 volts when fully charged. The six cells are connected together to produce a fully charged battery of about 12.6 volts.

3.Heat Sink
Heat sinks are one of the most common forms of thermal management in technology, machinery, and even in natural systems. These components are so ubiquitous that they're easy to overlook, even by those who are familiar with the technology. A heat sink is a component that increases the heat flow away from a hot device. It accomplishes this task by increasing the device's working surface area and the amount of low-temperature fluid that moves across its enlarged surface area. Based on each device's configuration, we find a multitude of heat sink aesthetics, design, and ultimate capabilities. You can see a straight fin heat sink in the image at the top of this article and a flared fin heat sink in the image below. Each heat sink is valuable in applications that may have varying.

4.Fan with Heat sink
The heat sink is a thermal conductive material that quickly carries heat away from the processor. It is designed to have the greatest amount of surface area in a small volume of space, so aside from the flat contact surface the heat sink has many thin "fins" that facilitate heat dissipation through thermal convection, which means the heat is further carried away from the heat sink itself by air. Often the normal flow of air is not enough to allow for quick cooling, so a fan has to be added. Together, the HSF is the least expensive cooling solution available, with efficiency varying according to the heat sink design and fan power

IV. **Experimentation Analysis**:-

Figure 2: Experimental Representation of Thermoelectric Water Cooler.

The experimental apparatus for thermoelectric water cooling system have been presented. It consists of heat sink, TEC, water container, fan, and two power supplies. In this study, a thermoelectric module TEC1-12706have been used. The thermoelectric module consists of 127 thermocouples. It connected in series and sandwiched between two ceramic plates. After applying electricity on the system, a ceramic plate works as a heated plate, while the other one works as a cooled plate. The direction of the current determines which plate is heated. The goal was to supply power to the thermoelectric modules using a DC power supply. The modules in turn will cool a container wherein water will be filled and tests be done. A container had to be fabricated of a material, which would easily conduct heat. The container has a cylindrical shape with diameter (100 mm) and high of (120mm). The base of the container is attached directly to the cold side of TE with thermal grease. The water containers have been insulated to diminish heat loss. To ensure best performance of TEC, the heat reduce from the hot side should be put out as much as possible. To dissipate this heat, a heat sink attached to the hot side in our module. The heat sink was used is the one, which is used typically in CPU's of the computers. It consists of two parts; one is a 12-volt dc fan and the other an aluminum finned surface Below the TEC sets of the module of the heat sink with proper thermal paste to ensure proper thermal contact. It has been made from aluminum. the size of the base is (77×68×10)mm3, and the length of the fins equal to (68mm) , where the height and thickness of the fins equal to (25mm) and (1mm) respectively. On the base of heat sink, 35 fins have been used with 1.2mm distance between then. A 12V fan is set below the heat sink and connected with another power supply. *To assess the validity of this optimum design results, an experiment had to be* conducted based on the optimum design input parameters. From the optimum design of the heat sinks, two commercial heat sinks with close geometry to the optimum values were selected to be used in the experimental work. The thermoelectric cooler also was chosen based on the optimum parameters results, and due to availability limitations, a similar module with close geometry was selected instead. The test stand accommodates two 40 × 40
ALPHA UB40-25B heat sinks at the cold and the hot sides and a 40 × 40 TB 127-1.4-1.15 thermoelectric module. It shows the test stand with removed isolation pads. These pads are extremely important to reduce the errors associated with heat convection

and radiation losses from the system. Once the optimum geometric parameters and the input power of the thermoelectric cooler are obtained analytically, the experimental work is conducted to evaluate the performance of the thermoelectric system. In the first step, highly conductive thermal paste was applied to reduce the thermal resistance between the interfaces of the TEC module and the aluminum blocks. The test stand was also bolted down using locking nuts to ensure the equal pressure is applied to all pins which can reduce the thermal resistances and provide efficient heat transfer from the module to the aluminum blocks and the heat sinks. Then, the input voltage is adjusted until the steady state conditions are reached and measurements are taken for the junctions and fluid inlet and exit temperatures at variable input voltages ranging from 0 to the maximum voltage provided by the module manufacturer.

V. **CALCULATIONS**:-

When the current is supplied to thermo electric cooler heat will be absorbed and rejected at the cold and the hot sides, respectively, which results in a difference in the junctions' temperatures. To maintain this temperature gradient, heat has to be rejected from the hot side. Otherwise, the two sides will reach thermal equilibrium leading to a rise in the temperature of the cold junction. To do that, heat sinks with forced conviction process using fans or blowers for air and pumps for liquid water configurations are recommended, depending on the system application. For the cold side, heat is absorbed from the air driven by fans to achieve cooling air with low temperatures. Through reversing the direction of the supplied current, heat dissipation at the hot side can also be used to produce heating by using forced air convection and heat sinks. In this case, the cold side should be as warm as possible to maximize the efficiency of heating on the hot side; this can be handled by applying forced convection at the cold side so that heat is absorbed from the ambient air to the cold heat sink to keep it warm. The volume flow rate at the two heat sinks can be easily varied by manipulating the input power to the fans, and the cooling or heating power can be changed depending on the demand by changing the input current to the thermoelectric cooler. The critical parameters when operating a thermoelectric cooler are the input current or voltage through the power supply and the cold and hot junction temperatures, which can be measured using thermocouples.

DTmax for module—the maximum temperature difference that can be achieved across the
ΔT = Th – Tc – 50°C – 10°C = 40°C

The thermoelectric elements within a module with zero watts of heat load and at Thot = 50°C °.
DTmax you enter should be greater than the temperature difference (DT) The current to maintain ΔT = 40°C, at the supplied voltage:

Consider, I = 3.77 A

The heat pumped from the, at I = 3.77 A and ΔT = 40°C:

Qc = 20.75 W

Vmax—the voltage that occurs when DTmax is produced.

Vmax = voltage drop across cooler

Vmax = Imax + S

I/Imax for lowest power—the ratio of the module's suggested operating current to the Imax of the module.
Imax = Current / I max module
= 121 amp

Seeback coefficient
S = |Sp|+|Sn| = 12 mile volt for temperature difference of 30 degree C

= 12 x 10 ^3 / 30
= 400 micro volt per degree C

Hence Vmax = 0.12 Volts

Qmax for lowest power is the Qmax of a module that has been optimized for minimum power consumption.

Qmax = S * Imax

= 400 x 10 ^3* 121

= 13 watt

Qmax for smallest size is the minimum Qmax of a module that will meet the cooling requirement.
This generally translates to a module that is as physically small as possible. Qmax capable of meeting the cooling requirements.

VI. **RESULT**:-

1.	*ΔT*	*= 40°C*
2	*T hot*	*= 50°C*
3	*Qc*	*= 20.75*
4	*Imax*	*= 121 amp*
5	*S*	*= 400 micro volt per degree C*
6	*Vmax*	*= 0.12 volts*
7	*Qmax*	*= 13 Watt*

Table 1. Results of Thermoelectric refrigerator

CONCLUSION:-

The conclusion of this thermoelectric water cooling system is

- The available thermoelectric water cooling system shows that thermoelectric cooling systems are generally only around 5–15% as efficient compared to 40–60% achieved by conventional compression cooling system.
- From the above data we can conclude that Thermoelectric cooling added a new dimension to cooling. It has major Impact over conventional cooling system.
- It is compact in size, no frictional elements are present, no coolant is required and weight of the system is low.
- From the review of the pertinent literature presented above, it can be inferred that thermoelectric technology using different modules used for cooling as well as heating application has considerable attention. Many researchers try to improve the power of the thermoelectric air conditioner using different material.

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