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Design, Manufacturing and Experimental Analysis of Thermoelectric Lunch Box

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Abstract
This paper discuss Design, Manufacturing and Experimental Analysis of thermoelectric refrigerator working on Peltier effect objective f the design is to maintain food at 40◦c and to reduce the water temperature by 5◦c.working model is manufactured and . Performance is observed under various conditions using graphical method conclusion is obtained.

Key words
Thermoelectric refrigerator, peltier effect. Coefficient of performance.

Introduction:-

Thermoelectric refrigerator a thermoelectric cooler module or Peltier cooler is a semiconductor based electric component that functions as a small heat pump. By applying a low voltage direct current (DC) power source to a thermoelectric cooler module, heat will be moved through one side to the other. One module face, will be cooled while the opposite face simultaneously is heated. Both thermoelectric refrigerators and mechanical refrigerators are governed by the same fundamental laws of thermodynamics and both refrigeration systems; although considerably different in form, function in accordance with the same principles. In a thermoelectric cooling system, a doped semi-conductor material essentially takes the place of the refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a Direct Current power source. At the cold end of the semi-conductor material, heat is absorbed by the electron movement, moved through the material, and expelled at the hot end. Since the hot end of the material is physically attached to a heat sink, the heat is passed from the material to the heat sink and then in turn, transferred to the environment [1].

1.1 PeltierEffect:

The Peltier effect is useful when it is necessary to transfer heat from one medium to another on a small scale. The Peltier effect is one of three types of thermoelectric effect; the other two are the Seebeck effect and the Thomson effect. In a Peltier-effect device, the electrodes are typically made of a metal with excellent electrical conductivity. The semiconductor material between the electrodes creates two junctions between dissimilar materials, which, in turn, creates a pair of thermocouple voltage is applied to the electrodes to force electrical current through the semiconductor, thermal energy flows in the direction of the charge carriers. Peltier-effect devices are used for thermoelectric cooling in electronic equipment and computers when more conventional cooling methods are impractical. The Peltier effect bears the name of Jean-Charles Peltier, a French physicist who in 1834 discovered the calorific effect of an electrical current at the junction of two different metals. When a Current (I) is made to flow through the circuit, heat is evolved at the upper junction (T2) and absorbed at the lower junction (T1). Peltier heat is reversible, when the direction of current is reversed; the Peltier heat is the same, but in opposite direction. Peltier coefficient depends on the temperature and materials of a junction.

Introduction to Thermoelectric module

Thermoelectric (TE) modules are small solid-state devices that function as heat pumps. A "typical" unit is a few millimeters thick by a few millimeters to a few centimeters square, as shown in below.

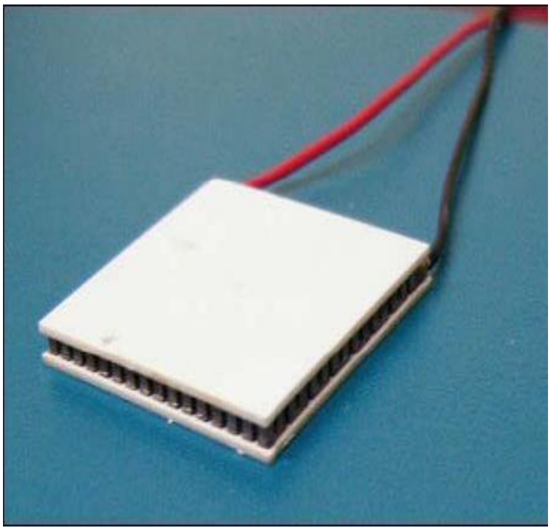


Figure 1 : Single stage module [2]

The ceramic material on both sides adds rigidity & necessary insulation. The electric conductors are usually made of copper and simply permit the flow of electrons. The cooling is proportional to the current and number of modules hence number of modules can be cascaded to achieve greater temperature difference.[2]
In a thermo electric module the heat transferred to hot side is greater than that pumped by a quantity to joules heating (I2R loss) hence a good thermoelectric material must have low thermal conductivity to prevent heat loss through heat conduction between hot and cold sides and a high electrical conductivity to minimize joules heating. The best material for semiconductors so far developed is bismuth telluride that satisfies this condition.

Significant features of the Thermoelectric modules are

 A thermoelectric module works electrically there is no moving part so they are virtually maintenance free.
 Small size and weight:- The overall thermoelectric cooling system is much smaller and lighter than a comparable mechanical system.
 Unlike a conventional heat sink a thermoelectric system attached to that same heat sink has the ability to reduce the temperature below the ambient value.
 Precise temperature control up to temperatures to better than +/-0.1˚C.
 Thermoelectric modules exhibit very high reliability due to their solid state construction. Although reliability is somewhat application dependent, the life of typical thermoelectric system is greater than 200,000 hours.
 Electrically Quite Operation: - unlike a mechanical refrigeration system, thermoelectric modules generate virtually no electric noise and can be used in conjunction with sensitive electronic sensors. They are also acoustically silent.
 Operation in any Orientation:- Thermoelectric modules can be used in any orientation and in zero gravity environments. Thus they are popular in many aerospace applications.
 Convenient Power Supply: - Thermoelectric modules operate directly from a DC power source.
 Spot Cooling:- With a thermoelectric module it is possible to cool one specific component or area only, thereby often making it necessary to cool an entire package or enclosure.
 Ability to Generate Electric Power: - When used ‘in reverse’ by applying a temperature differential across the faces of a thermoelectric refrigeration system, it is responsible to generate a small amount of DC power.
 Environmental Friendly: - Conventional refrigeration system cannot be fabricated without using chlorofluorocarbons or other chemicals that may be harmful to environment. Thermoelectric devices do not use or generate gases of any kind.
 Thermoelectric devices convert thermal energy directly into electricity, or vice-versa. Direct conversion eliminates losses associated with multiple energy conversion processes. [2]

Fabrication

Following components were selected and used for fabrication of project with modification and skill where ever needed so as to carryout experiments. Following is a brief overview of the components that are used.

- Stainless steel 304.
- Stainless steel 202.
- Galvanized steel.
- Copper plate 24 gauge.
- Peltier plate
- Wires.
- SMPS/DC Power supply
- Sub- zero.

Assembly

- Assemble the circuit box &make the connection between SMPS & Sub-zero.
- Place the peltier plate between hot & cold compartments by using heat paste.
- Then place the compartments on the circuit box.

Testing

Initial testing:-

- Testing was carried out in open conditions.
- Ambient temperature was 28 degree.
- During this test, the temperature was 42 degree on hot side & 10 degree on cold side.
- We had used copper plate on cold side & aluminum heat sink on hot side.
- Water was used to dissipation of heat from hot side of plate by using heat sink.
- From above values of temperature we were satisfy.

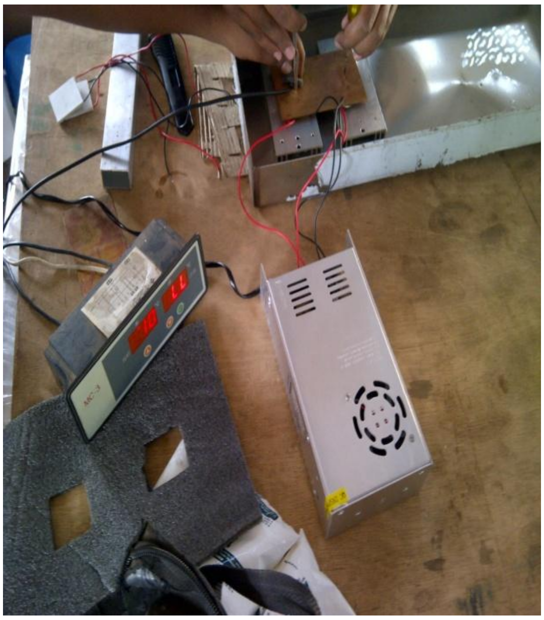
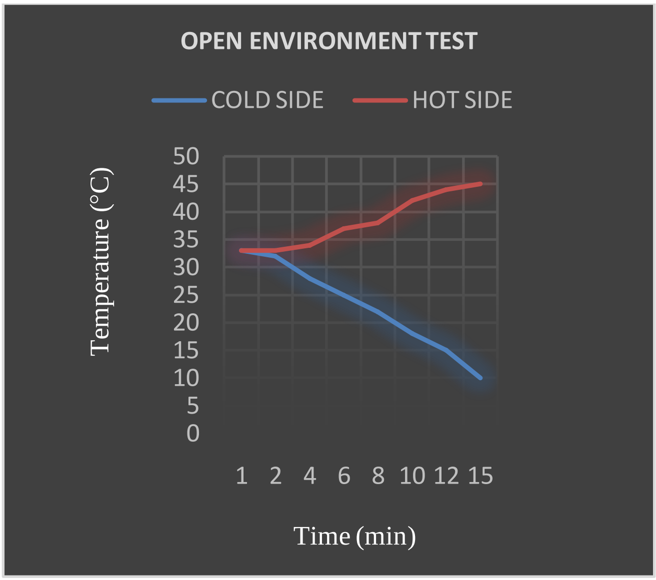


Figure 2: Initial Test



Graph 1: Open environment test

➢ **Observation table:-**

Sr no	Minute	Hot Temperature	Cold temperature
1.	1	33	33
2.	2	33	32
3	4	34	28
4	6	37	25
5	8	38	22
6	10	42	18
7	12	44	15
8	15	45	10

Table 1: Initial test

Final testing

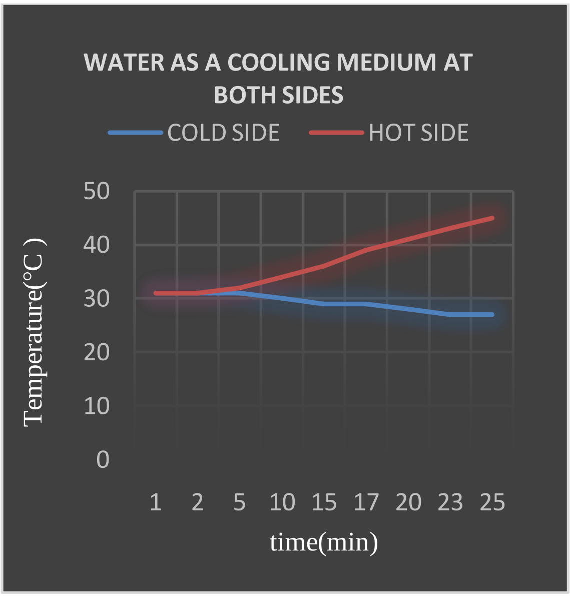
Using water in both compartments:-

- Test was carried out after finishing of design.
- Water was poured in both compartment.
- The quantity of water required in hot side is 1.5 liters &1 liter in cold side
- Ambient temperature was 31 degree.
- Following result was found.

➢ **Observation table:-**

Sr no	Minute	Hot Temperature	Cold temperature
1.	1	31	31
2.	2	31	31
3	5	32	31
4	10	34	30
5	15	36	29
6	17	39	29
7	20	41	28
8	23	43	27
9	25	45	27

Table 2: Final Test 1



Graph 2: Water as a cooling medium

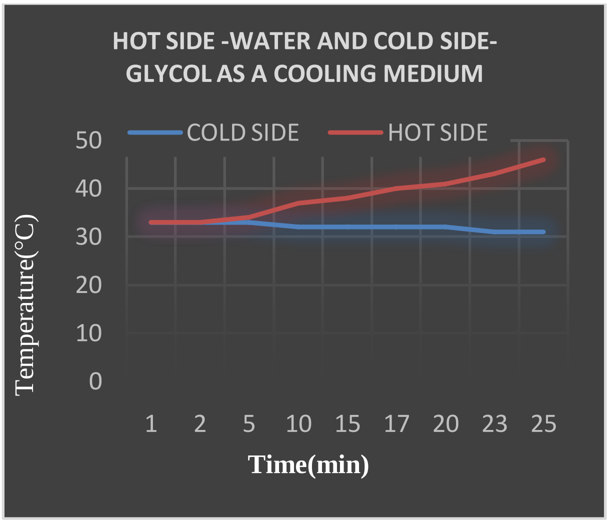
Using Glycol at cold side & Water at hot side.

- Test was carried out after finishing of design.
- Water &Glycol was poured in corresponding compartment.
- The quantity of water required in hot side is 1.5 liters & 1 liter mixture in cold side.
- Mixture contains 30% Glycol & 70% water.
- Ambient temperature was 33 degree.
- Following result was found.

➢ **Observation Table**:

Sr no	Minute	Hot Temperature	Cold temperature
1.	1	33	33
2.	2	33	33
3	5	34	33
4	10	37	32
5	15	38	32
6	17	40	32
7	20	41	32
8	23	43	31
9	25	46	31

Table 3: Final test 2



Graph 3: Water at hot side and Glycol at cold side as a cooling medium

CALCULATION

Required Data:

- **Weights:**
  1. Total wt. = 0.615 Kg (Empty)
  2. Single piece = 0.115 Kg
  3. Roti = 0.220 Kg
  4. Rice = 0.260 Kg
  5. Vegetable = 0.285 Kg
  - **Specific Heat (Cp):-**
  1. Water = 4.187 KJ/Kg.K
  2. Air = 1.005 KJ/Kg.K
  3. Copper = 0.381 KJ/Kg.K
  4. Chicken = 4.34 KJ/Kg.K
  5. Vegetable = 3.90 KJ/Kg.K
  6. Rice = 3.60 KJ/Kg.K

- **Formula**
  Q = m*Cp*(T2-T1)

- **Calculation**
  1. Q water =m*Cp*(T2-T1).
     = 1.488*4.187*(285)
     = 1.775.62 KJ.
  2. Q air = m*Cp*(T2-T1).
     =1.05*1.005*(285)
     =300.75 KJ.
  3. Q chicken=m*Cp*(T2-T1).
     =0.250*4.34*(285)
     = 309.225 KJ.
  4. Q vegetable= m*Cp*(T2-T1).
     = 0.250*3.90*(285)
     = 277.88 KJ.
  5. Q rice = m*Cp*(T2-T1).
     = 0.250*3.90*(285)
     = 256.5 KJ

Application

- Personnel Water cooler & Food Heater for working Class also for pantry use.
- To refrigerate blood during transport to distant remote areas.
- In hospitals for food as well as for surgery tools and equipment.
- In food malls for quick & safe service of hot & cold products.

Conclusion

After putting many efforts, we have successfully completed the project. As per our requirements, it is seen that temperature is maintain in between 25 to 45 degrees as per requirement without much human intervention. Hence, we guarantee that if our prototype design is adapted by various refrigeration manufacturers, it will be beneficial and economical at the same time to the end users.

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