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Design and Analysis of Thermoelectric Refrigerator cum Oven

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Abstract : ***In recent trends with increase awareness towards environmental pollution due to to the production, use and discharge of choloroflоro carbon (CFC) and Hydrocholorofloro carbon (HCFC) as a refrigerant for heat carrier in conventional refrigeration system has become a subject of great concerned and result in extension research into development of refrigeration technology. Thermoelectric Refrigeration is new era as alternative because it can convert waste electricity into useful cooling, is expected to play an important role in today's refrigeration system.***

In this project we have use thermoelectric module for cooling and heating effect the precise develop cooling power below which the thermoelectric method is preferable thermoelectric cooler is solid state heat pump which uses semiconductor material by peltier effect,to provid intaneous cooling or heating.It has the advantage of having no moving parts like compressor, condenser, evaporator and dust maintenance free. The thermoelectric refrigeration have been design and developed an experimental thermoelectric refrigeration system having refrigeration space of 2.5 lit is cooling by three module and heat sink fan assembly for thermoelectric module to increase heat dissipation rate . The rejected heat has been utilized for piazza heating

I. INTRODUCTION

The basic concept behind thermoelectric (TE) technology is the Peltier effect—a phenomenon first discovered in the early 19th century. The Peltier effect occurs whenever electrical current flows through two dissimilar conductors. Depending on the direction of current flow, the junction of the two conductors will either absorb or release heat. Explaining the Peltier effect its operation in thermoelectric devices, is a very challenging proposition. It ultimately keys on some very complex physics at the sub-atomic level. Here we will attempt to approach it from a conceptual perspective with the goal of giving readers an intuitive grasp of this technology.

II. THERMOELECTRIC MODULE

The TEM operating principle is based on the Peltier effect. The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material to create a hot side and a cold side. The cold side of the thermoelectric module is utilized for refrigeration purposes; provide cooling to the refrigerator space. On the other hand, the heat from the hot side is utilized for heating purpose In a thermo-electric heat exchanger the electrons acts as the heat carrier. The heat pumping action is therefore function of the quantity of electrons crossing over the p-n junction.

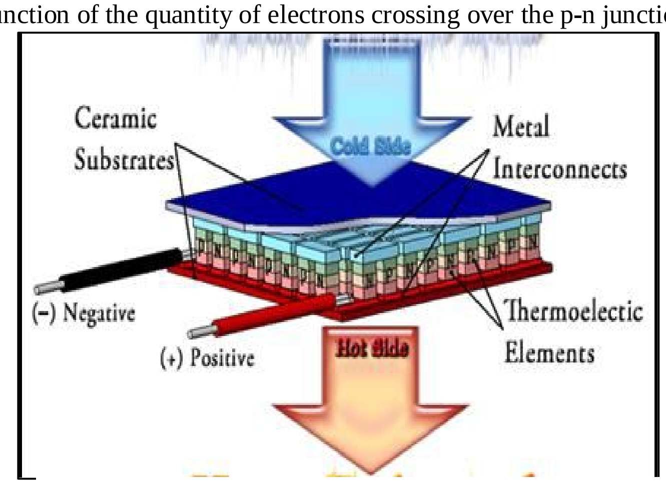

Figure 1 : Thermoelectric Module

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III. WORKING OF THERMOELECTRIC MODUL

Thermoelectric modules are solid-state heat pumps that operate on the Peltier effect A thermoelectric module consists of an array of p- and n-type semiconductor elements that are heavily doped with electrical carriers. The elements are arranged into array that is electrically connected in series but thermally connected in parallel. This array is then affixed to two ceramic substrates, one on each side of the elements (see figure below). Let's examine how the heat transfer occurs as electrons flow through one pair of p- and n-type elements (often referred to as a "couple") within the thermoelectric module.

The p-type semiconductor is doped with certain atoms that have fewer electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, there is a tendency for conduction electrons to complete the atomic bonds. When conduction electrons do this, they leave "holes" which essentially are atoms within the crystal lattice that now have local positive charges. Electrons are then continually dropping in and being bumped out of the holes and moving on to the next available hole . In effect, it is the holes that are acting as the electrical carriers.Now, electrons move much more easily in the copper conductors but not so easily in the semiconductors. When electrons leave the p-type and enter into the copper on the cold-side, holes are created in the p-type as the the electrons jump out to a higher energy level to match the energy level of the electrons already moving in copper. The extra energy to create these holes comes by absorbing heat. Meanwhile, the newly created holes travel drop downwards to the copper on the hot side. Electrons from the hot-side copper move into the p-type and into holes, releasing the excess energy in the form of heat. The n-type semiconductor is doped with atoms that provide more electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, these extra electrons are

IV. CONSTRUCTION

A thermoelectric refrigeration cabinet with refrigeration space 44cm x31cmx13cm cabinet 1 A thermoelectric oven cabinet with refrigeration space 44cm x31cm x 21 cm cabinet 2. Volume of cabinet 1 is 17732 cm^3. outer casing of MS sheet 50 cm x 34cm x 42.5 cm.A thin galvanized sheet (0.4 mm) has been fixed inside the box for uniform distribution of temperature. For thermal insulation a polyurethylene foam liquid is provided inside the box to prevent reversal of heat flow. A Three numbers of thermoelectric modules (TEC 1-12706) have been used to reduce inside temperature of refrigeration space

V. EXPERIMENTAL SETUP

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First of all two compartments are made of the conducting material and coated with foam insulators. These are fixed as an assembly in a box made up of a aluminium material for ventilation and support Three thermoelectric modules are attached to the whole setup. Operating load can be taken from charge controller or through direct battery. A photo voltaic module attached with a charge controller is place in the sun at a proper position to get the most area of it in the sunlight.Thermoelectric semiconductor material used is Bismuth telluride. This charge controller is then attached to the battery. Now the whole setup is powered by the solar energy and working is obtained.

VI. OBSERVATION TABLE

Time [min] T	Cooling compartment temperature [˚C] Tc	Hot Side Temp T_{hot}	Mass of Water (Mw)	Sp.Heat Cp	*Temp Dif. ΔT*	Cooling capacity Q = M × C × ΔT	Tsec	Q in Watt	W in =no. Of Batteries xVxI	COP = Q/W
0	44.2	44.2	0.5	4186	*0*	0	0	0	88	0
5	44	44.6	0.5	4186	*0.6*	1255.8	300	4.186	88	0.047568182
10	43.2	45.2	0.5	4186	*2*	4186	600	6.976667	88	0.079280303
15	42.2	47	0.5	4186	*4.8*	10046.4	900	11.16267	88	0.126848485
20	40.1	47.4	0.5	4186	*7.3*	15278.9	1200	12.73242	88	0.144686553
25	39.2	47.8	0.5	4186	*8.6*	17999.8	1500	11.99987	88	0.136362121
30	38.4	49	0.5	4186	*10.6*	22185.8	1800	12.32544	88	0.140061869
35	37.4	49.3	0.5	4186	*11.9*	24906.7	2100	11.86033	88	0.134776515
40	36.5	49.8	0.5	4186	*13.3*	27836.9	2400	11.59871	88	0.131803504
45	35.3	50.8	0.5	4186	*15.5*	32441.5	2700	12.01537	88	0.1365383
50	34.2	51.6	0.5	4186	*17.4*	36418.2	3000	12.1394	88	0.137947727
55	33.8	52.7	0.5	4186	*18.9*	39557.7	3300	11.98718	88	0.136217975
60	32.4	53.4	0.5	4186	*21*	43953	3600	12.20917	88	0.13874053
65	31.5	54.2	0.5	4186	*22.7*	47511.1	3900	12.18233	88	0.138435606
70	29.8	55.2	0.5	4186	*25.4*	53162.2	4200	12.65767	88	0.143837121
75	27.8	56.2	0.5	4186	*28.4*	59441.2	4500	13.20916	88	0.15010404
80	25.1	56.8	0.5	4186	*31.7*	66348.1	4800	13.82252	88	0.1570741
85	24.2	57.9	0.5	4186	*33.7*	70534.1	5100	13.83022	88	0.157161542
90	23.3	59.2	0.5	4186	*35.9*	75138.7	5400	13.91457	88	0.15812016

VII. CALULATION FOR COP

When the designed solar thermoelectric refrigerator was tested with Forced convection with cooling fan running . It was found that the inner temperature of the refrigeration area was reduced from 44.2 ˚C to 23.3 ˚C in approximately 90 min, a difference of 20.9˚C. Below is an example, which shows how the coefficient of performance of the refrigerator [COP] was calculated.

The refrigerator is used to cool a 0.3Liter of water

Properties of water are:- Density = 1000 Kg/m³ ;Specific heat = 4.186 KJ/KgK

Mass of water, M = ρ × V = 1000 × 0.5 × 0.001= 0.5 Kg ; Where ρ is density if water ; C_P is Specific heat of water

Cooling capacity Q = M × C_P × ΔT

= 0.5 × 4186 × [59.2-23.3] = 75138.7 J

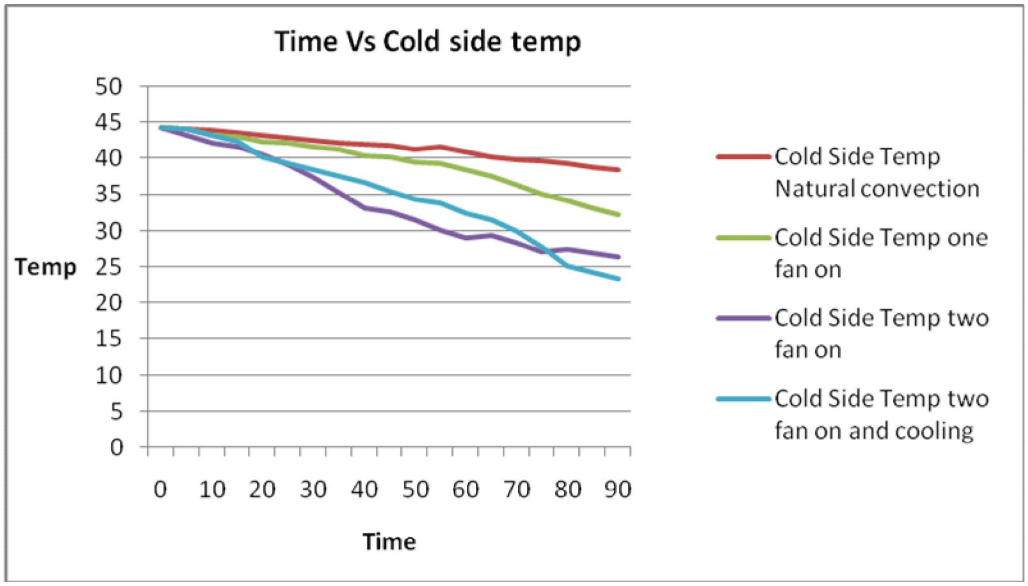
Q_C = 75138.7 J = 75138.7 /90*60 = 13.91 W

Work input W = Number of Batteries × V × I = 2 × 12 × 3.4 = 88 W

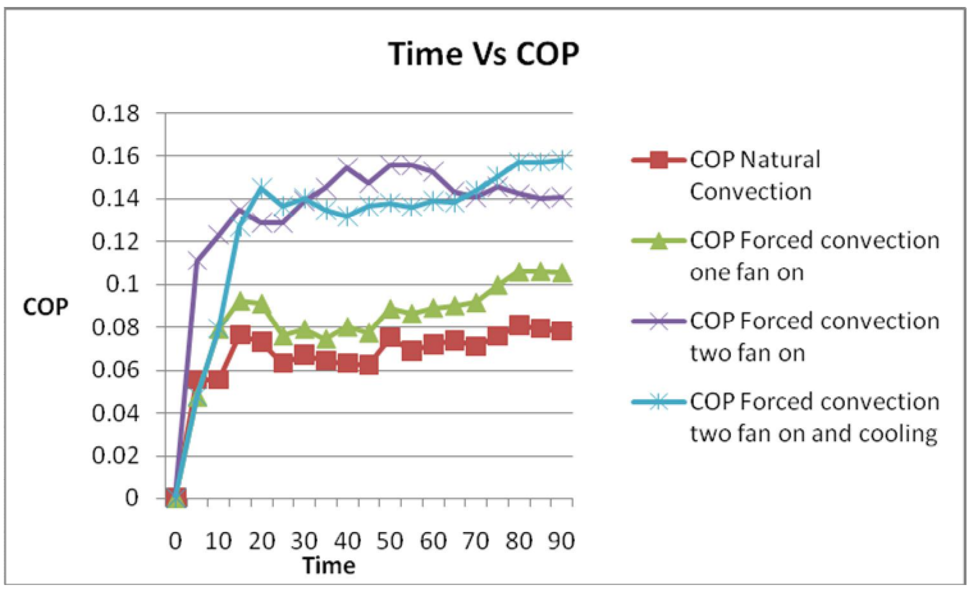
Coefficient of Performance COP = Q / W = 13.91/88 = 0.1581

VIII. RESULTS AND DISCUSSION

First experiments were conducted for performance evolution of above specified three thermoelectric cooling modules. Experiments carried for four various heat transfer methods 1.Natural Convection 2. Force convection with one fan on 3.Force convection with Two fan on 4.Force convection with cooling by water



The COP of the device throughout the test was also calculated. Figure 3 , below, shows the relationship between efficiency and time for each of the tests. The COP increases with increasing change in temperature and with the highest temperature change tested (59.2°C), the maximum COP was 0.158



IX. CONCLUSION

In this work, a portable solar thermoelectric refrigerator unit was fabricated and tested for the cooling heating purpose. The refrigerator was designed based on the principle of a thermoelectric module to create a hot side and cold side. The cold side of the thermoelectric module was utilized for refrigeration purposes whereas the rejected heat from the hot side of the module was utilized for heating purpose. In order to utilize renewable energy, solar energy was integrated to power the thermoelectric module in order to drive the refrigerator. Furthermore, the solar thermoelectric refrigerator avoids any unnecessary electrical hazards and provides a very environmentally friendly product. In this regard, the solar thermoelectric refrigerator does not produce chlorofluorocarbon (CFC), which is believed to cause depletion of the atmospheric ozone layer. In addition, there will be no vibration or noise because of the difference in the mechanics of the system. In addition the rejected heat from the solar thermoelectric refrigerator is negligible when compared to the rejected heat from conventional refrigerators.

A. Advantages

We believe that thermoelectric cooling offers a number of advantages over traditional refrigeration methods, as:

1) System have no moving parts,
2) No Freon's or other liquid or gaseous refrigerants required,
3) Precise temperature control,
4) High reliability & durability - We guarantee 5 years hours of no failures,
5) Compact size and light weighted,
6) Noiseless operation,
7) Relatively low cost and high effectiveness,
8) Easy for maintenance,
9) Eco-friendly C-pentane, CFC free insulation.

B. Disadvantage

1) C.O.P. is less as compared to conventional refrigeration system.
2) Suitable only for low cooling capacity

C. Applications Of Systems

1) Medical and pharmaceutical equipment,
2) Military applications,
3) Laboratory, scientific instruments, computers and video cameras.
4) In restaurants /hotels

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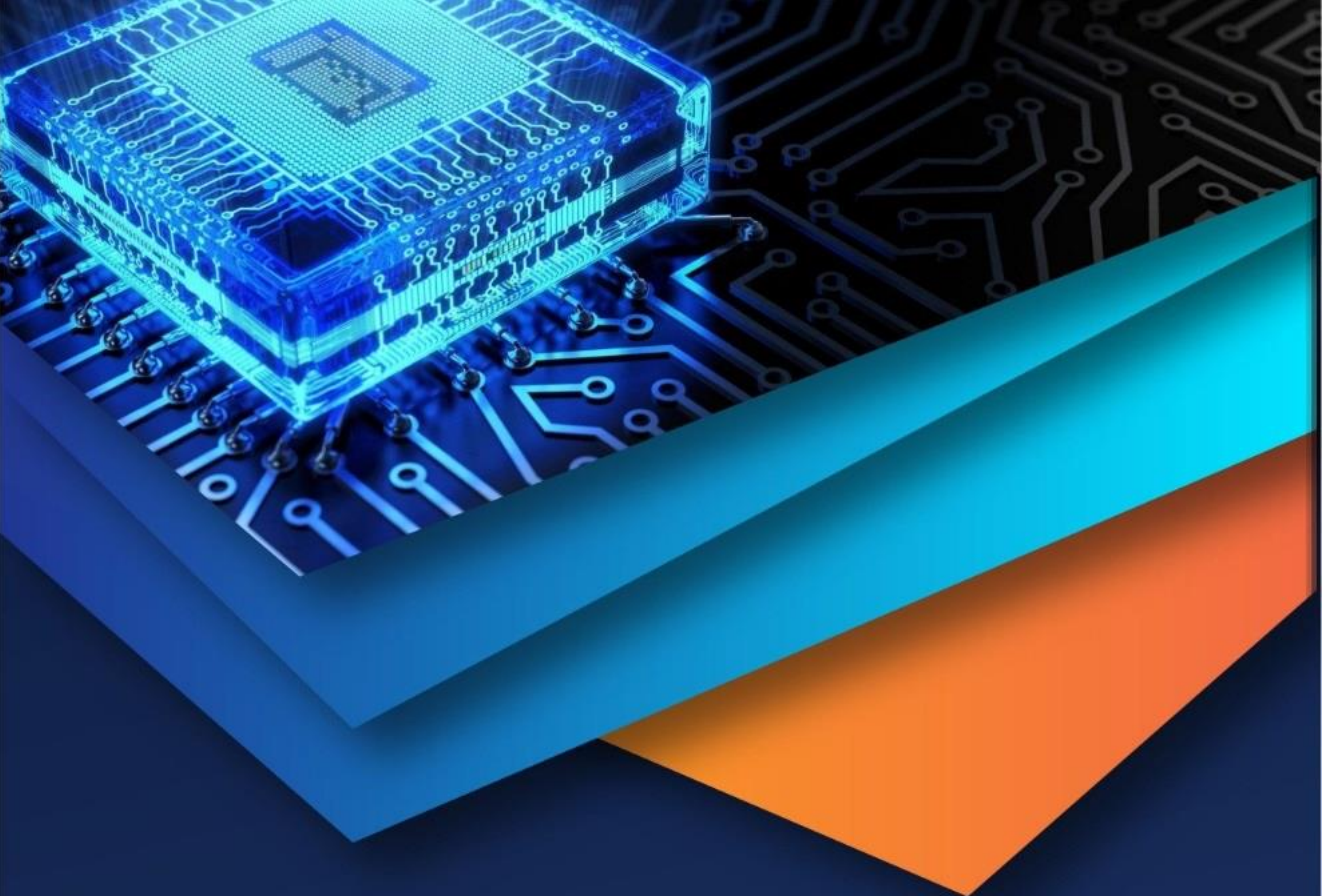

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