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Research Papers

DESIGN AND DEVELOPMENT OF SOLAR WATER COOLER

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Abstract

In recent years, with the increase awareness towards environmental degradation due to the production, use and disposal of ChloroFluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs) as heat carrier fluids in conventional refrigeration and air conditioning systems has become a subject of great concern and resulted in extensive research into development of novel refrigeration and space conditioning technologies and also facing the electricity crisis. It's time to harness the renewable sources of energy of nature.

The project uses the solar energy to run the system.In this project a thermoelectric system is fabricated. It is an eco-friendly project made by using a thermoelectric module. The project has a various applications in military and aerospace.The main objective of the project is to cool the water by using Thermoelectric Module or peltier.Inpeltier,when voltage is applied temperature difference occurred hence one side is having cooling effect and another side is having heating effect and that heat is removed by heat sink and by using forced convection around heat sink rate of heat transfer is increased and hence sufficient cooling of water is obtained.

Thermoelectric Module works on the principle of PeltierEffect.So temperature difference occurred.As a result one side is having cooling effect and another side is having heatingeffect.HencePeltier can be used as cooler on one side and heat pump on another side.The project uses renewable source of energy called Solar Energy to run system and not using any Refrigerants and not having more Mechanical components. Hence the project is more efficient and economic.

KEYWORDS:

Thermoelectric system, Thermoelectric Module,chlorofluro carbons.

INTRODUCTION

The current tendency of the first world is to look at renewable energy resources as a source of energy. This is done for the following two reasons; firstly, the lower quality of life due to air pollution; and secondly, due to the pressure of the ever increasing world population puts on our natural energy resources. From these two facts comes the realization that the natural energy resources available will not last indefinitely. Therefore, the ideal solution would be to use some type of renewable energy resource to provide these house with energy without an expensive electrical grid connection.One of the main application renewable source of energy called Solar Energy finds application in Refrigeraton.

Refrigeration is a process in which work is done to move heat from one location to another. The work of heat transport is traditionally driven by mechanical work, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to refrigeration units.

The state-of-the-art of solar cooling has concentrated primarily on the developmental stages of systems in the last few years. Various methods have been researched and some demonstrated, but only a few systems have been installed for other than research purposes. Solar cooling systems are attractive because cooling is most needed when solar energy is most available.Solar cooling systems by themselves, however, are usually not economical at present fuel cooling systems is not easy because of the different system requirements. This can best be understood by summarizing the different solar cooling techniques. As with solar heating, the techniques for solar cooling consist of passive systems and active systems. For active solar cooling systems the three most promising approaches are the heat actuated absorption machines, the Rankine cycle heat engine and the desiccant dehumidification systems.

The project uses the solar energy to run the system.In this project a thermoelectric system is fabricated. It is an eco-friendly project made by using a thermoelectric module for cooling purpose.
The main components used in this system are Peltier, Heat Sink, Gear pump, Solar Panel and Battery.

A.Methods of refrigeration

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

Cyclic refrigeration can be classified as:

1.Vapour cycle
2.Gas cycle

Vapour cycle refrigeration can further be classified as:

1.Vapour-compression refrigeration.
2.Vapour-absorption refrigeration.

B.Objectives of the project:

1.Usage of Renewable source of Energy called solar Energy to run the system.
2.To meet better cooling performance.
3.To reduce the cost of the project as much as possible.
4.Usage of solid state heat pump called peltier.

LITERATURE SURVEY

Thermoelectric devices are solid state devices. They are reliable energy converters and have no noise or vibration as there are no mechanical moving parts. They have small size and are light in weight. As refrigerators, they are friendly to the environment as CFC gas or any other refrigerant gas is not used. Due to these advantages, the thermoelectric devices have found a large range of applications. The prospects of the applications of the thermoelectric devices are also discussed.[1]A system design method of thermoelectric cooler is developed in the present study. The design calculation utilizes the performance curve of the thermoelectric module that is determined experimentally. An automatic test apparatus was designed and built to illustrate the testing. The performance test results of the module are used to determine the physical properties and derive an empirical relation for the performance of thermoelectric module. These results are then used in the system analysis of a thermoelectric cooler using a thermal network model. The thermal resistance of heat sink is chosen as one of the key parameters in the design of a thermoelectric cooler. The system simulation shows that there exists a cheapest heat sink for the design of a thermoelectric cooler. It is also shown that the system simulation coincides with experimental data of a thermoelectric cooler using an air-cooled heat sink with thermal resistance 0.2515°C/W. An optimal design of thermoelectric cooler at the conditions of optimal COP is also studied. The optimal design can be made either on the basis of the maximum value of the optimal cooling capacity, or on the basis of the best heat sink technology available.[2]

1.PROBLEM IDENTIFICATION AND CONCEPT GENERATION

After studying the several journals on solar water cooling system using peltier effect it is essential to implement the project in order to get better cooling performance and also make the project more economical.

In this project work various heatsink concepts are generated and problems regarding the various heatsink concepts are identified and selected the best concept using concept screening and concept scoring method for further progress of the project.

Concept A:Circular fin Heatsink

Figure a: Circular fin Heatsink

In this concept,

1.Thermal Resistance is 2.54 deg c/watt.
2.Thermal conductivity is 205 w/mk.
3.Heatsink is made up of Aluminium material.
4.Surface area is less.
5.Cost is less.

CONCEPT SELECTION PROCESS

CONCEPT SCREENING

Concept screening is based on a method developed by the late Stuart Pugh in the 1980s and is often called Pugh concept Selection. The purpose of this stage is to narrow the number of concepts quickly and to improve the concepts. Based on the concept screening we have selected a concept and the selection procedure is as follows:-

Step 1: Prepare the selection Matrix.
Step 2: Rate the concepts.
Step 3: Rank the concepts.

Step 4: Select one or more concepts.

Step 1: Prepare the selection matrix

The selection matrix is an input of selection criteria and the concepts where the concepts are rated against the selection criteria. Concepts should be presented at the same level of detail for meaningful comparison and unbiased selection. The selection criteria are listed along the left hand side of the screening matrix, as shown in the table below.

These criteria are chosen based on the customer needs as well as on the needs of the enterprise, such as low manufacturing cost or minimal risk of Product liability. The criteria at this stage are usually expressed at a fairly high level of abstraction and typically include from 5 to 10 dimensions.

Step 2: Rate the concepts

A relative score of “better than” (+), “same as” (0), “Worse than” (-) is to be place in each cell of the matrix to represent how each concept in comparison to the reference concept B relative to the particular criterion.

Here the concept B is selected to develop the breadboard the reason behind this is Particular concept is that it is straightforward and promising concept with which the team members are very familiar with it.

Ratings:- “better than” (+), “same as” (0), “Worse than” (-)

Table A: List of concepts

Concept A	Circular fin Heatsink
Concept B	Plate fin Heatsink
Concept C	Elliptical fin Heatsink
Concept D	Rectangular fin Heatsink.

Rank the concept

Table:B Concept screening matrix

Selection criteria	Concept A	Concept B	Concept C	Concept D
Thermal Resistance	+	+	_	+
Thermal Conductivity	+	+	+	+
Material	_	+	_	-
Surface area	0	_	0	+
Cost	+	_	+	+
SUM +’S	3	3	2	4
SUM 0’S	1	0	1	0
SUM –‘S	1	2	2	1
Net score	2	1	0	4
Rank	2	3	4	1

After rating all the concepts, summation of the “better than”, “same as”, “Worse than” scores and enters the sum for each category in the lower rows of the matrix. A net score is calculated by subtracting the number of “Worse than” ratings from “better than” ratings. In general, the concept with more ratings will be ranked higher and the outcome of this step is that concept “D” is ranked as “1”.

2.Geometric 2D and 3D Modelling

In the above concept selection process,concept D is selected.So for the further development process,2D and 3D modelling is done using Solid EdgeV19 software.

Following are the 2D and 3D models of individual components.

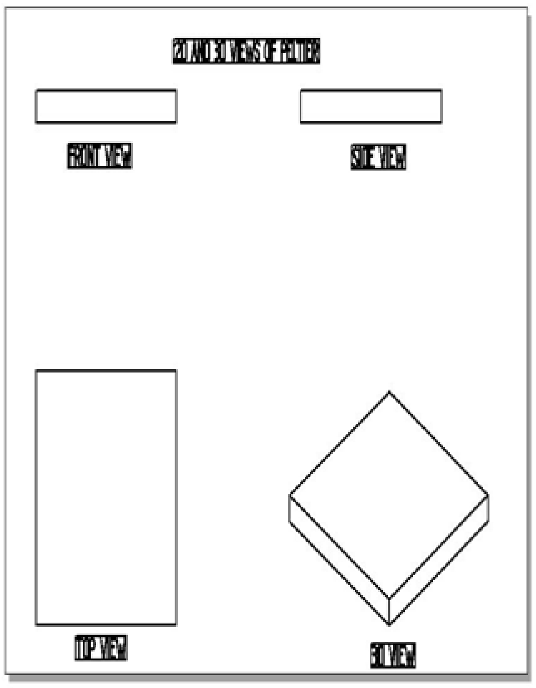


Fig :A 2D and 3D view of Peltier

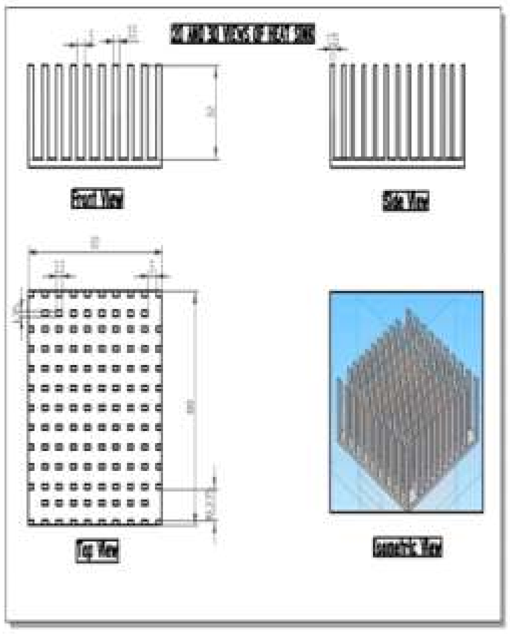


Fig:B 2D and 3D view of Heat Sink

COMPONENT DESIGN

Here Design calculations of Heat Sink are done by taking peltier as reference.Ifsome amount of electricity is supplied to peltier,one side gets cooler and other side becomes hotter.so in order to dissipate heat to atmosphere Heat Sink is used and by using forced convection rate of heat transfer can be increased.

1.DESIGN OF HEAT SINK:

Design parameters of heat sink:

Table:A. Design Parameters of Heat Sink

SI NO	Design parameters	Value
1	Thermal resistance	3.84 deg c/watt
2	Lengh of the heat sink	80mm
3	Breath of heat sink	80mm
4	Height of fin	32mm
5	Thickness of base plate	3mm
6	No of fins	126
7	Distance between each fin	5mm

Dimensions of one fin of heat sink
Height of the fin=32mm
length of the fin=3mm
breadth of the fin=1.75mm

Equations involved in design of Heat Sink
1.q=hA? T
whrere h=convective heat transfer co efficient in $w/m^{2\,0}c$
A=surface area of heat sink in mm^2
? $T=(T_{hs}-T_a)$

2.q=mc_p? T
Where q=heat transfer rate in watts
m=mass flow rate of water in litre/min
cp=specific heat of water.
? $T=(T_{out}-T_{in})$.
R=1/h
Therefore h=1/R=1/3.84=0.2604 $w/m^{2\,0}c$
Q=VI
=14.4*4.2
Q=60.48watts

To Determine Surface Area of Heat Sink
Total Surface Area of Heat Sink= Area of Pin+Area of Plate
1.To find area of pin:
A_{pin}=2*3*32+2*1.75*32+1*3*1.75
=309mm
total no of fins=126
Therefore A_{pin}=309*126
$A_{pin}=38934mm^2$

2.To find area of plate:
length*breadth=80*80
= (80*80-126*3*1.75)
Aplate=5738mm2
Total Surface Area of Heat Sink=38934+5738
=44672mm^2

,
q=hA? T
? T=q/hA
=39.56/0.2604*44672
=39.56/11632.588
? T = 0.003124
T_{hs}-T_a=0.006124
T_{hs}=0.006124+300
T_{hs}=30.0030c
To determine mass flow rate of water
q_{water}=mc_p? T
q_{wate}r=1*4.184(T_{out}-T_{in})
=4.184(35-30)
qwater =20.92watts

Out of 92.16watts given to peltier,20.92watts of heat is dissipated by forced convection and remaining heat is dissipated by Heat Sink.

WORKING PRINCIPLE

In Thermoelectric Refrigeration System, the main component is Thermoelectric module or peltier.The following is brief explaination on working principle of Thermoelectic Module.

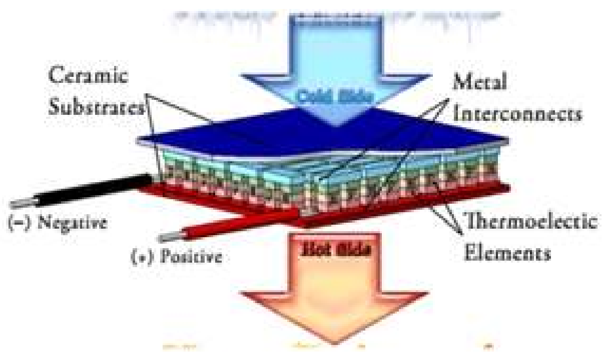


Fig: A.Thermoelectric Module

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. Thermoelectric modules are solid-state heat pumpsthat operate on the Peltier effect (see definitions). A thermoelectric module consists of an array of pandn-type semiconductor elements that are heavily doped with electrical carriers. The elements arearranged into array that is electrically connected inseries but thermally connected in parallel. This array is then affixed to two ceramic substrates. Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator or thermoelectric cooler (TEC).

OPERATION

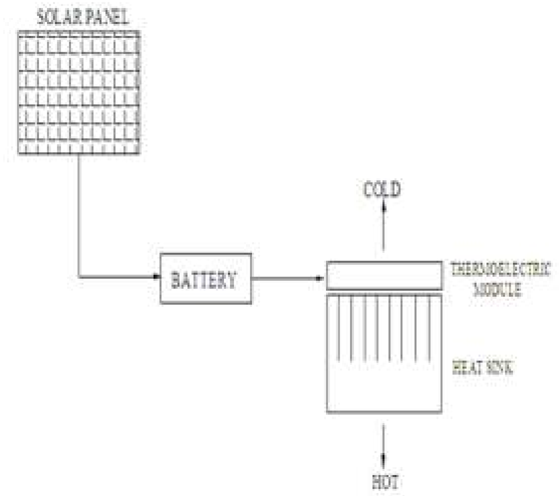


Fig:B Block Diagram of the System

The main aim of the project is to implement the solar in the cooling of the water; The implementation consists of components like solar panel which helps to converts solar energy to the electrical energy which is stored in the battery. Thermoelectric module is mounted on the exhaust fins and the pump is used for forced convection. Therefore solar energy stored in the battery is utilized for the working of the Thermo electric module.

DESCRIPTION OF THE COMPONENTS

The major components in Thermoelectric Refrigeration system are as follows,

SOLAR PANEL

Fig:A Solar Panel

A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells.The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications.

Currently the best achieved sunlight conversion rate (solar module efficiency) is around 21.5%. The most efficient mass-produced solar modules have energy density values of up to 175 W/m2 (16.22 W/ft2).

THERMOELECTRIC MODULE

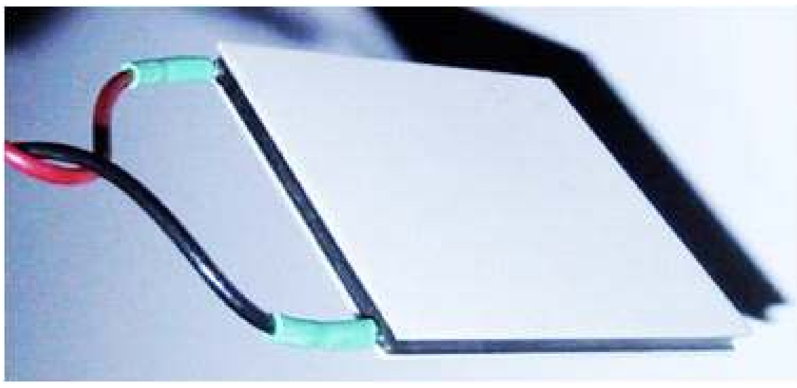


Fig B. Typical 40x40mm Peltierelement

Thermoelectric modules are solid-state heat pumpsthat operate on the Peltier effect. A thermoelectric module consists of an array of pandn-type semiconductor elements that are heavily doped with electrical carriers. The elements arearranged into array that is electrically connected in series but thermally connected in parallel. This array is then affixed to two ceramic substrates. Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy

HEAT SINK

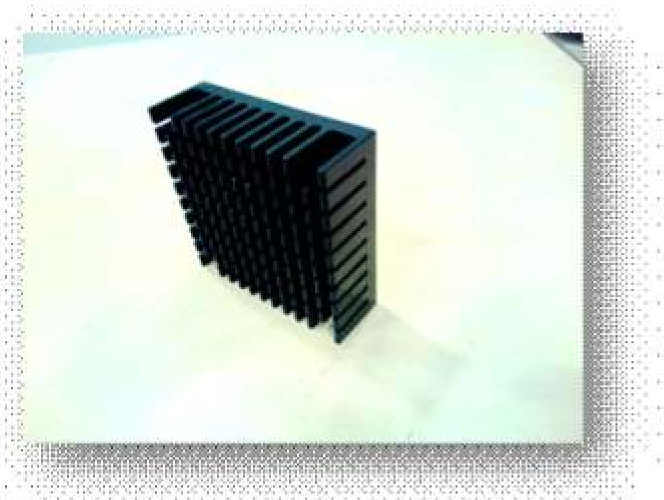


Fig C. Heat Sink

In electronic systems, a heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. In computers, heat sinks are used to cool central processing units or graphics processors. In this project heat sink is used to dissipate the heat to surroundings from peltier.

BATTERY

Fig: D Battery

In isolated systems away from the grid, batteries are used for storage of excess solar energy converted into electrical energy. To be economically attractive the storage of solar electricity requires a battery with a particular combination of properties:

Low cost
Long life
High reliability
High overall efficiency
Low discharge
Minimum maintenance
Ampere hour efficiency
Watt hour efficiency

The project lead acid battery for storing the electrical energy from the solar panel.

GEAR PUMP

A pump is a device that moves fluids (liquids or gases) or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps.

Pumps can be classified by their method of displacement into positive displacement pumps, impulse pumps, velocity pumps, gravity pumps, steam pumps and valveless pumps.
Gear pump is rotory positive displacement pump.

Fig:EGear Pump

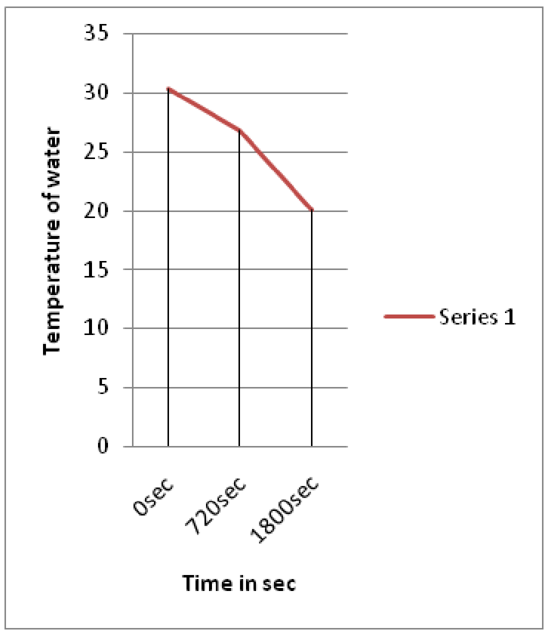
The project uses gear pump in order to circulate water around heat sink to dissipate heat by forced convection.

PHOTOGRAPH OF THE PROJECT

Fig:FPhotograph of solar water cooler

RESULTS AND DISCUSSIONS

If 14 watts ofpower is applied across the pelteir,temperaturediffirence occurs and hence cooling of water takes place.The below graph suggests the initial and final temperature of water when 14 watts of power is applied across the peltier for 30 minutes.



Graph A

In order to cool the water in Refrigeration systems, heat dissipation is very essential. It can be done by water or air.In this project work heat dissipation is done by water.The above graph shows the reduction in temperature of water with respect to time.The Rate of cooling depends on heat dissipation. Rate of cooling gets faster as heat dissipation gets faster. In the above graph which suggests that at 0sec, the temperature of water is 30.3^{0}C and at 720sec ,the temperature of water reduces to 26.8^{0}C.The difference is reduction in 3.4^{0}C in almost 12 minutes.The experiment is carried out for next 18minutes,temperature of water becomes 20.1^{0}c. Temperature difference of 10.2^{0}c is observed between initial temperature and final temperature which a better cooling performance.This is possible when water is circulated around heat sink from inlet and allowed to flow at oulet.

CALCULATION

Initial temperature of liquid in the containerbefore cooling = T_1 = 30.3^{0}c
Final temperature of liquid in the containerafter cooling = T_2 = 20.1^{0}c
Mass of water = M_w = 0.058705kg
Time taken to cool the water = t =30mins
Specific heat of water = CP_w = 4.187KJ/Kg
Heat transfer rate = Q = M_w*CP_w*(T_1-T_2) KW
t
Q = 0.058705*4.187*(30.3-20.1) KW
30*60
Q=1.39285*10^{-3}KW
One ton of refrigeration = 3.5 KW
Therefore, ton of refrigeration =1.39285*10^{-3}/3.5 KW
ton of refrigeration= 3.9795*10^{-4}KW

ADVANTAGES

1.Reduced size and weight compared to the absorption cycle system and compressor system.
2.Reliable solid state cooling with no sound, vibrations or electromagnetic radiation.
3.Precision temperature control could be achieved by just varying the input power to the TEC
4.TEC's can be cascaded to produce temperature differences between the hot side and the cold side of more than half .

APPLICATIONS

1.They are used for fibre optic and other electro-optic cooling applications.
2.Food service refrigeration and other commercial/institutional applications.
3.Appliances such as portable 12V refrigerators, water and beverage coolers, etc.
4.Instruments for physical, chemical, optical and electronic analysis.
5.Medical and pharmaceutical equipment.
6.Military/aerospace applications (noise free and compact cooling).

SCOPE FOR FUTURE WORK

1.In this project as water is fed at inlet and allowed at outlet, more water is required for forced convection and it time consuming. So for further progress of the project a proper system to dissipate the heat of water at the outlet and circulate the water again to inlet should be maintained which results in less consumption of water for forced convection, reduction in time and better cooling performance.
2. Nano fluids can be used for forced convection instead of water which increases the rate of heat dissipation.
3.In this project work gear pump is used to ciculatewater,instead of that water can be drawn due gravity from inlet to outlet which inturn reduces the cost of the project.

CONCLUSION

So by using this project better cooling performance is observed.This cooling technique does not have any moving parts and not using any harmfull refrigerants. Peltier can be used as cooler on one side and heater or heat pump on another side.So project is more efficient and cost effective than any other cooling systems.

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