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EXPERIMENTAL INVESTIGATION OF THERMOELECTRIC AIRCONDITIONER USING SEEBECK MODULES

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Abstract

The optimization of Thermo Electric Air Conditioners (TEAC) has been a challenging topic due to the multitude of variables needed to be considered. The present air-conditioning system produces cooling effect by refrigerants like Freon, Ammonia etc. Using these refrigerants can get maximum output but one of the major disadvantages is harmful gas emission and global warming.
These problem can be overcome by using thermoelectric modules (Seebeck effect) air-conditioner and their by protecting the environment.
The increase in demand for refrigeration globally in the field of air-conditioning, food preservation, medical services, vaccine storages, and for electronic components temperature control led to the production of more electricity and consequently an increase in the CO2 concentration in the atmosphere which in turn leads to global warming and many climatic changes
Thermoelectric refrigeration is a new alternative because it can reduce the use of electricity to produce cooling effect and also meet today's energy challenges. The problem can be overcome by using thermoelectric modules (Seebeck effect) air-conditioner and their by protecting the environment. Therefore, the need for thermoelectric refrigeration in developing countries is very high where long life and low maintenance are needed.
The present project deals with the study of Thermoelectric air conditioner using different modules is discussed. Thermoelectric cooling systems have advantages over conventional cooling devices, such as compact in size, light in weight, high reliability, no mechanical moving parts like compressors and no working fluid like primary refrigerants

1. INTRODUCTION

Air conditioner equipment power is often described in terms of "tons of refrigeration." A "ton of refrigeration" is defined as the cooling power of one short ton (2000 pounds or 907 kilograms) of ice melting in a 24-hour period. This is equal to 3517 watts. Residential central air systems are usually from 1 to 5 tons (3 to 20 kilowatts (kW)) in capacity. The use of electric/compressive air conditioning puts a major demand on the electrical power grid in hot weather, when most units are operating under heavy load.The effect of air-conditioning demand makes the energy consumption has been increasing quickly. The investigation report shows that of the total energy consumption in buildings in Metro city, the energy amount used by air-conditioning system is 46.1% in restaurant building, 40.5% in commercial building, 49.7% in office building, and 30.3% in

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hospital building. The ever increasing energy requirement puts a great burden on the further economical development as India is poor in energy resources. How to reduce the energy consumption by using new energy saving technologies and equipment is an important task now days. In order to reduce the energy consumption in air-conditioning building, apparatus dew-point air supply is usually used in air-Conditioning systems. But as the moist air leaving the cooling coil is usually too high in relative humidity (about 95% Rh) and too low in temperature to be used in occupied spaces directly, people usually feel uncomfortable.

My aim is to introduce the new HVAC system using thermoelectric couple which shall overcome all the disadvantages of existing HVAC system. If this system comes in present HVAC system, then revolution will occur . With population and pollution increasing at an alarming rate TEC (thermoelectric couple) system have come to rescue as these are environment friendly, compact and affordable.

Conventional compressor run cooling devices have many drawbacks pertaining to energy efficiency and the use of CFC refrigerants. Both these factors indirectly point to the impending scenario of global warming. As most of the electricity generation relies on the coal power plants, which add greenhouse gases to the atmosphere is the major cause of global warming. Although researches are going on, better alternatives for the CFC refrigerants is still on the hunt. So instead of using conventional air conditioning systems, other products which can efficiently cool a person are to be devised. By using other efficient cooling mechanisms we can save the electricity bills and also control the greenhouse gases that are currently released into the atmosphere.

Although Thermoelectric (TE) property was discovered about two centuries ago thermoelectric devices have only been commercialised during recent years. The applications of TE vary from small refrigerators and electronics package cooling to Avionic instrumentation illumination control and thermal imaging cameras. Lately a dramatic increase in the applications of TE coolers in the industry has been observed. It includes water chillers, cold plates, portable insulin coolers, portable beverage containers and etc.

1.1 PROJECT OBJECTIVE

1. To study critically existing HVAC system for its advantage and disadvantages.
2. To explore various technological option to replace existing HVAC system.
3. To study TEC as a substitute for present HVAC system which will overcomes the all demerits of present HVAC system.
4. To fabricate working model of HVAC using TEC.
   To test HVAC using TEC for its effectiveness, efficiency, environment friendliness, comfort and convenience

1.2 SCOPE OF PROJECT

Why Thermoelectric cooling for HVAC.

Power loss – Compressor is driven by the crankshaft of the engine. It consumes 5 to 10% of engine power. Fuel loss – Present HVAC System reduces the mileage of the vehicle.

Electrical heat loss – during the step up and step down process and ac to dc conversion process

Cost – cost of present HVAC System is very high.

Hazardous refrigerant – HFC is quit hazardous for human body & ozone layer which leads to global warming. Repairing cost – Repairing cost of HVAC System is very high.

Maintenance – Proper maintenance is very necessary because this system can affect human body & Environment.
Size –Present HVAC system required very large space in the engine compartment and dashboard.
Delicate system –if any component fails to perform well then the whole HVAC system will either not function properly or not function at all.
The project scope involves the following elements sizing and designing of cooling system

- Selection of the TECs
- Selection of Fans and Heat sinks
- DC power supply design with temperature control.
- Prototype Assembly and Fabrication.
- Temperature measurements for testing.
- Power supply testing and troubleshooting.

2. LITERATURE SERVEY

Kumar Rawat et al studied experimentally that, Thermoelectric Refrigeration system and they have been designed and developed an experimental thermoelectric refrigeration system having a refrigeration space of 1 liter is cooling by four numbers of thermoelectric cooling module (Qmax=19W) and a heat sink fan assembly (Rth=0.50 ºC/W) for each thermoelectric module used to increase heat dissipation rate. A temperature reduction of 11º C without any heat load and 9º C with 100 ml of water in refrigeration space with respect to 23º C ambient temperature has been experimentally found in first 30 minutes at optimized operating conditions. The calculated COP of thermoelectric refrigeration cabinet was 0.1. Also compatibility of thermoelectric cooling systems with solar energy made them more useful and appropriate for environment protection. **C. K. Loh, Danie** studied experimentally, that characterize the heat sink performance is often performed under different procedures and apparatuses specifically catered to the knowledge of the individual in the thermal testing laboratory. When simulating the heat load of the electronics package, the conventional practice is to use resistance heating elements such as cartridge resistive heaters or flexible thin film heaters. Recently, thermoelectric devices (TED) are also being used as the heat source in heat sink laboratory experiments. The primary benefit of using a TED as a heat source in laboratory testing is that the TED is a unidirectional heat pump. All input electrical power is discharged to the TED hot side when properly used. This unidirectional heat pump process provides a more conservative experimental result, especially when calculating the experimental heat sink resistance. Contrarily to a TED, the resistance heater is a heat diffusion device, where the heat is dissipated to the surroundings by conduction. Even when the heater is fully insulated on all sides but the heat sink, a portion of heat is still lost to the ambient through the insulation. The effect is less energy passes to the heat sink than is inputted to the resistive heater.

3. PRINCIPLES OF THERMOELECTRICS

A thermoelectric (TE) cooler, sometimes called a thermoelectric module or Peltier 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. It is important to note that this phenomenon may be reversed whereby a change in the polarity (plus and minus) of the applied DC voltage will cause heat to be moved in the opposite direction. Consequently, a thermoelectric module made used for both heating and cooling thereby making it highly suitable for precise temperature control applications.

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).

Both thermoelectric coolers 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 mechanical refrigeration unit, a compressor raises the pressure of a liquid and circulates the refrigerant through the system. In the evaporator or "freezer" area the refrigerant boils and, in the process of changing to a vapour, the refrigerant absorbs heat causing the freezer to become cold. The heat absorbed in the freezer area is moved to the condenser where it is transferred to the environment from the condensing refrigerant. In a thermoelectric cooling system, a doped semiconductor material essentially takes the place of the liquid refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a DC power source. The application of DC power to the thermoelectric module causes electrons to move through the semiconductor material. At the cold end (or "freezer side") of the semiconductor 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.

The physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800's, although commercial TE modules were not available until almost 1960. The first important discovery relating to thermoelectricity occurred in 1821 when a German scientist, Thomas Seebeck, found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals provided that the junctions of the metals were maintained at two different temperatures. Seebeck did not actually comprehend the scientific basis for his discovery, however, and falsely assumed that flowing heat produced the same effect as flowing electric current. In 1834, a French watchmaker and part time physicist, Jean Peltier, while investigating the "Seebeck Effect," found that there was an opposite phenomenon whereby thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit. Twenty years later, William Thomson (eventually known as Lord Kelvin) issued a comprehensive explanation of the Seebeck and Peltier Effects and described their interrelationship. At the time, however, these phenomena were still considered to be mere laboratory curiosities and were without practical application.

In the 1930's Russian scientists began studying some of the earlier thermoelectric work in an effort to construct power generators for use at remote locations throughout the country. This Russian interest in thermoelectricity eventually caught the attention of the rest of the world and inspired the development of practical thermoelectric modules. Today's thermoelectric coolers make use of modern semiconductor technology whereby doped semiconductor material takes the place of

dissimilar metals used in early thermoelectric experiments.
The Seebeck, Peltier, and Thomson Effects, together with several other phenomena, form the basis of functional thermoelectric modules. Without going into too much detail, we will examine some of these fundamental thermoelectric effects.

3.1 SEEBECK EFFECT:

To illustrate the Seebeck Effect let us look at a simple thermocouple circuit as shown in Figure (1.1). The thermocouple conductors are two dissimilar metals denoted as Material x and Material y.

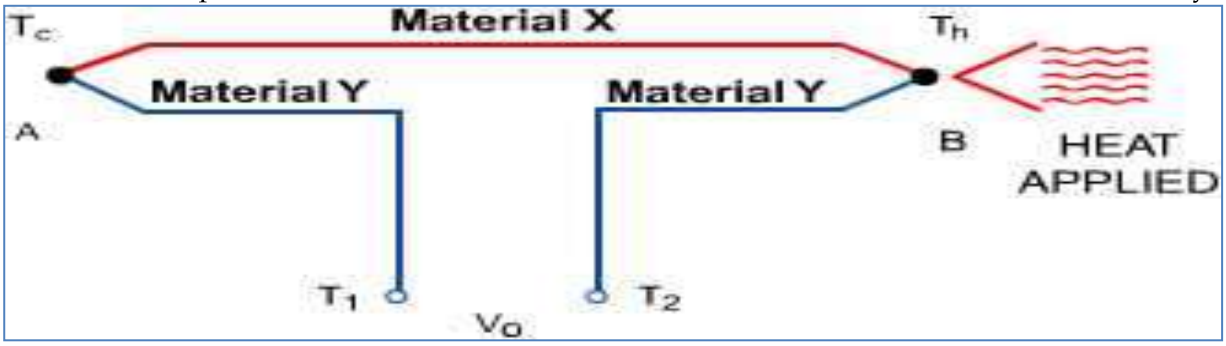


Fig. Seebeck effect thermoelectric circuit

In a typical temperature measurement application, thermocouple A is used as a "reference" and is maintained at a relatively cool temperature of Tc. Thermocouple B is used to measure the temperature of interest (Th) which, in this example, is higher than temperature Tc. With heat applied to thermocouple B, a voltage will appear across terminals Tl and T2.

3.2 PELTIER EFFECT:

If we modify our thermocouple circuit to obtain the configuration shown in Figure it will be possible to observe an opposite phenomenon known as the Peltier Effect

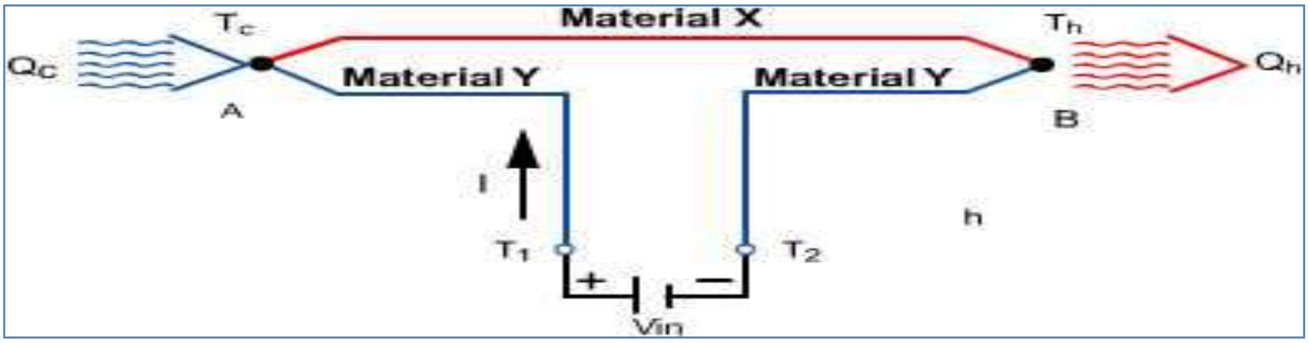


Fig. Peltier effect thermoelectric circuit

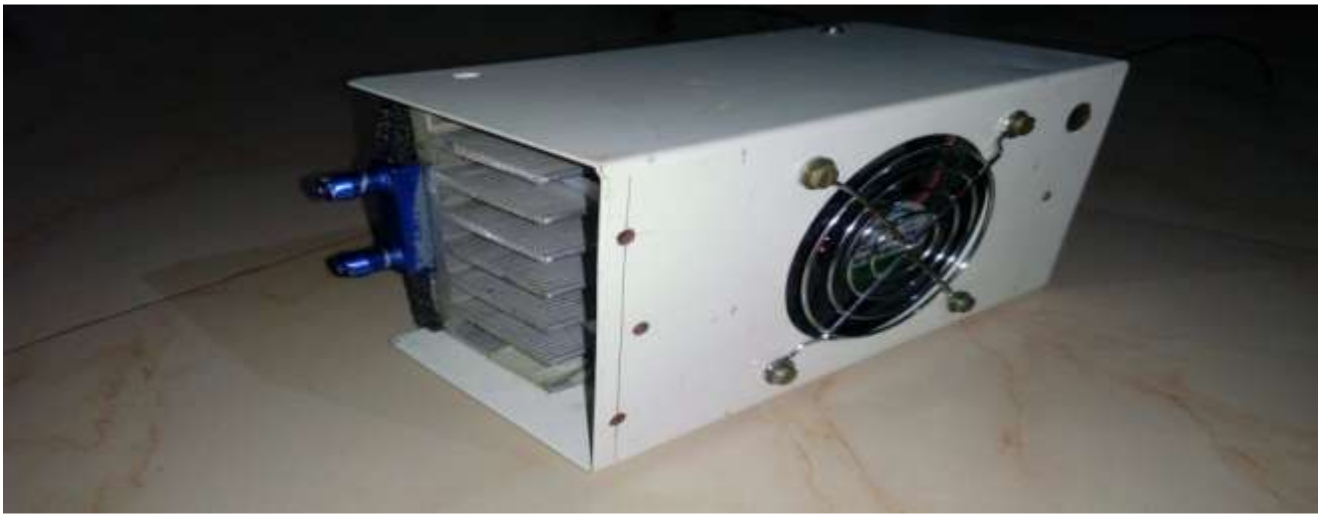
If a voltage (Vin) is applied to terminals $T_1$and T_2 an electrical current (I) will flow in the circuit. As a result of the current flow, a slight cooling effect (Qc) will occur at thermocouple junction A where heat is absorbed and a heating effect (Qh) will occur at junction B where heat is expelled. Note that this effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow.

3.3 THOMSON EFFECT:

When an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor. Whether heat is absorbed or expelled depends upon the direction of both the electric current and temperature gradient. This phenomenon, known as the Thomson Effect, is of interest in respect to the principles involved but plays a negligible role in the operation of practical thermoelectric modules. For this reason, it is ignored.

4. FABRICATION OF EXPERMENTAL SETUP

4.1 COLD SIDE UNIT



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- This unit consists of aluminum water block attached with hot side of the tec and aluminium heat sink on cold side of tec all three are sandwiched with thermal grease and packed
- Fan will circulate the air passing through the fins of aluminum block
- The condensed water from the radiator enters into the aluminum water block from water inlet and leaves by taking heat from water outlet
- The entire unit is placed insidethe insulated box with 25 denser and having 40 litres volume
- Test lamp is placed inside the insulated space to add heat load to be tested

Fig. Cooling unit with test lamp under insulated condition

4.2 HOT SIDE UNIT

- Hot side unit consists of water cooled tube finned condenser with forced cooling system
- Priming pump is placed between outlet of condenser and inlet of aluminium water block
- The hot water from the aluminium block enters into condensing unit and gets cooled

5. CALCULATIONS

5.1 System Design

Our known design values are:

Q = 500Watt heat load

$T_A = 30^0C$ maximum ambient air temperature

$T_C = 16^0C$ required temperature of the cabin

Then identify the hot side temperature (T_H) and the resultant temperature differential across the module (ΔT). The temperature at the hot side will be equal to the sum of ambient temperature (T_A), the rise in temperature across the heat sink from rejecting the heat load (Q) and the TE module power (V x I).

$T_H = T_A + (V \times I + Q) R_Q$

Where,

R_Q is the thermal resistance of heat sink in ^0C temperature rise per Watt dissipated. In this design, we will keep the rise of temperature of the heat sink to not more than about 15^0C above ambient. This would give us a thermoelectric module hot side temperature of about 45^0C.

$T_H = 30^0C + 15^0C = 45^0C$

The temperature differential across the thermoelectric module can be calculated as follows:

$\Delta T = T_H - T_C = 45^0C - 16^0C = 39^0C$

5.2 Experimental Investigation

An experimental and performance analysis on fabricated thermo electric refrigerator was conducted. The cold end of the thermoelectric module was used in the system to cool the refrigerator cabin and a digital thermo meter is used to measure the temperature. The hot end is attached to a heat sink for heat rejection. In order to validate the performance of the system cool down experiment was conducted on the system.

5.3 Cool down test

For analyzing the performance of system, water load is considered as the active heat load to the system. Water at 33˚C was filled in the container before switching ON the system. The temperature at every 10 min.intervel was tabulated. The readings were recorded for 120 mins.

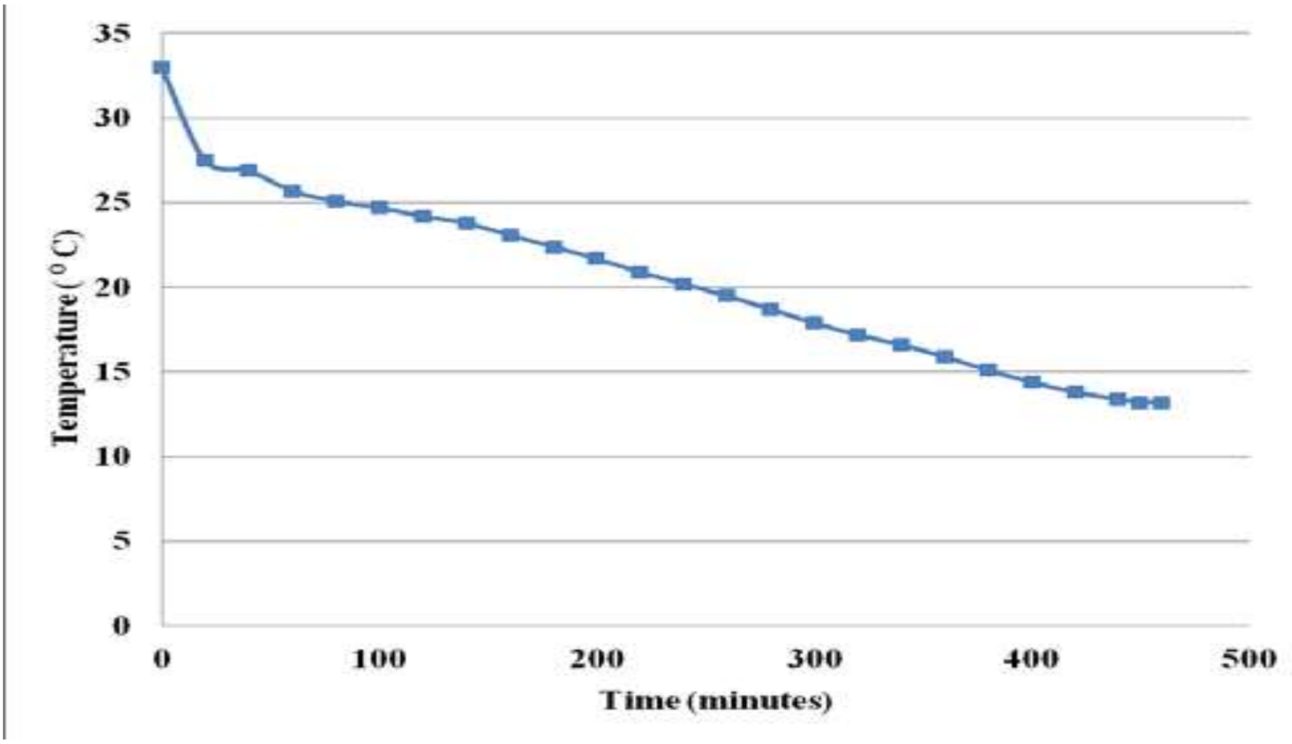

Fig. Variation of temperature with time

Even though the conventional system is mainly designed for maintain a fixed temperature, the above cool down experiment was proved that the system can be adapted for sensible cooling also. The figure shows the variation of temperature with time in the given setup. The lower steady temperature was attained around 13^{o}C at a time of 120 minutes. It took about 2 hours and to attain the same from 30^{o}C (ambient temperature).The cabin temperature drop was at an average rate of 8.5^{o} per hour.at 12v 16A to 3 peltiers

5.4 Performance of the thermoelectric air conditioner:

The active heat load is expressed as the equivalent cooling power that the unit will need to provide when the sample at ambient temperature is placed in the container. It was decided that two liter of water at room temperature took as the test sample .When the designed thermoelectric refrigerator was tested, it was found that the inner temperature of the refrigeration area was reduced from 30 ˚C to 13.2 ˚C in approximately 120 min. Coefficient of performance of the refrigerator (COP_R) was calculated. Water is used in place of vaccine for taking measurements and calculation. In these calculations, the properties of water are

(density = 1 kg/L and C_p = 4187 J/kg).V = 2 L.

Coefficient of performance of the refrigerator (COP_R) was calculated, *cooling R in Q* COP_R= $Q_{cooling}/W_{in}$

$Q = m\, C_p \Delta T$
Mass of water, m = density x volume = 2 kg
Total heat removed from the water = 166642.6 J

Qcooling = Q/Δ T =166642.6/450X60 = 6.17w
Power given to the system for working,
W_{IN} = V x I + fan input
= 12 x 4 + 2
= 50 W
Coefficient of performance of this refrigeration system is given by,
COP = $Q_{COOLING}$ / W_{in} = 6.17/50 = 0.124

COP of this refrigerator system is lower than conventional refrigerator. This is because the efficiency of thermoelectric modules is usually four times lesser than that of vapour compression system. And the heat leakage is also detected through doors; this too reduces the efficiency of the system.

6. CONCLUSION

From the Environmental point of view this system is Eco-friendly as it involves the seebeck module which is not responsible for OZONE layer Depletion. In this way we can concluded, technically, that higher COP can be obtained at low power input, thereby it reduces energy consumption rate. It offer following advantage with respect to the window air conditioner: No chlorofluorocarbons, Temperature control to within fractions of a degree can be maintained, Flexibleshape (form factor); in particular, they can have a very small size. The main disadvantages are initial investment is high and efficiency is slightly lower than normal air conditioner.

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