Chapter

Theoretical and Experimental Analysis of a Thermoelectric Air-conditioning System

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Abstract

Thermoelectric devices use the Peltier effect that creates a heat flux between the junctions of two different types of materials. The thermoelectric module also referred to as a heat pump transfers heat from one side to the other when a DC current is applied. This study carried out the theoretical analysis of a thermoelectric air conditioning system. A prototype thermoelectric air conditioner of 286 W cooling capacity was built and a testing enclosure made from plywood and Styrofoam was also constructed in order to validate the theoretical result with an experimentation. It was discovered that thermoelectric air conditioning took 4 minutes to reach its desired temperature of 22°C, whereas the standard air conditioning system (refrigeration cycle) took 20 minutes to cool to a room temperature. Economically, it was also discovered that thermoelectric air conditioning system is 50% cheaper than the refrigeration cycle air conditioning systems. The thermoelectric air conditioner has cheaper maintenance and greater estimated life span of 7 years more than the refrigeration air conditioner. This is because the air conditioner that operates on the refrigeration cycle uses a rotating compressor, while the thermoelectric air conditioner uses thermometric module.

Keywords: thermoelectric, Peltier effect, coefficient of performance, refrigeration cycle

1. Introduction

Air conditioning systems that uses the refrigeration cycle are the most common types of devices that uses air to exchange heat in an occupied space such as a building or a car. These systems consume a lot of electricity, can be bulky and some of the refrigerants used in the system is harmful to the environment. Therefore, there is the need for an alternative air conditioning system, thermoelectric modules are capable of generating both hot and cold temperatures at each side and as such can be used as an alternative to the present system. Although thermoelectric air conditioning systems have many advantages, they are rarely used due to having a lower efficiency as compared to conventional air conditioning systems [1]. It is therefore necessary to design a thermoelectric air conditioning system to achieve similar performance to that of a conventional AC system and also to have less disadvantages by designing a compact and light weigh prototype.

2. Brief history of thermoelectric principles

In the 1820s, it was found that the temperature difference of two dissimilar metals when in contact with each other produced an electromotive force of voltage. This voltage was produced since the temperature difference causes the electrons or other charged carriers to move from the hot side to the cold side of the metal which produced a current as shown in in **Figure 1**. This theory was found by Thomas Seebeck and is known as the Seebeck effect [2].

Approximately 10 years later, a physicist, Jean Peltier found that the reverse of the Seebeck effect is also true. He found that if a current was passed through different metals, the temperature at one side of the metal would increase while at the other side the temperature would decrease. This effect is known as the Peltier effect. The Peltier module work as a heat pump, such that at the cold side of the module, it absorbed the heat to be removed to the other side of the module when a DC voltage is applied [3].

2.1 Operating principle of the refrigeration cycle

The air conditioner consists of two connected coils which contains continuous flowing refrigerant inside of it. The split unit systems are the most common type of air conditioner, in which the coil located inside the room to be cooled is referred to as the evaporator and the coil located outside the room is called the condenser [4].

The operating principle of the refrigeration cycle is to keep the evaporator colder than the temperature of the room and the condenser temperature higher than the surroundings as shown in **Figure 2**. These conditions allow for the continuous flowing fluid to absorb the heat from the room and then eject the heat into the surroundings.

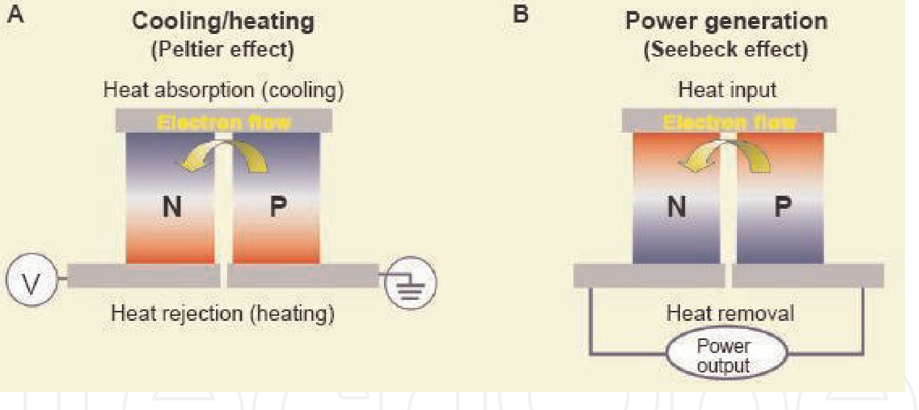


Figure 1.
Thermoelectric principle.

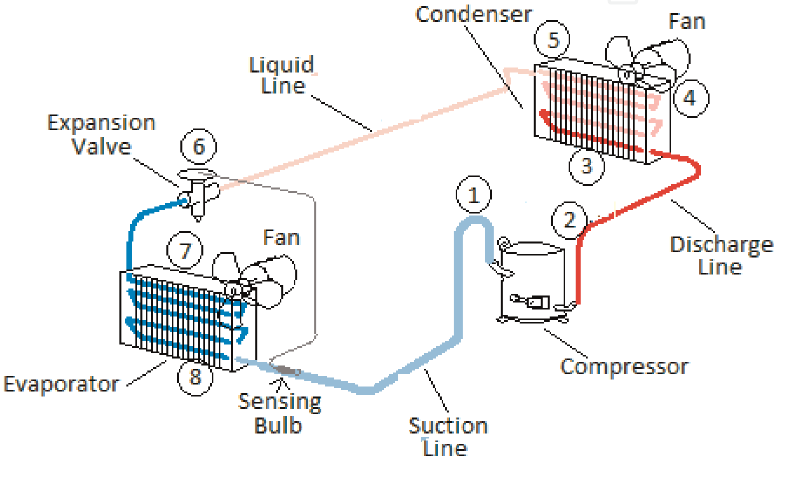


Figure 2.
Refrigeration cycle.

A compressor and an expansion valve are used to achieve these conditions. The compressor, usually a reciprocating compressor, is used to increase the pressure of the refrigerant. The refrigerant in the gaseous state enters the compressor and it is compressed which increases the temperature and pressure of the refrigerant. The temperature at the outlet of the compressor would be much greater than the atmosphere; therefore, when the hot gas passes through the condenser, the heat is easily rejected with the aid of a fan.

During the heat ejection phase, the gas is condensed into a liquid. At the exit of the condenser, an expansion valve is used to reduce the pressure of the fluid and also the temperature drops, which is lower than the room temperature. This is how the cold refrigerant is produced inside an air conditioner.

When the air is passed through the evaporator's coil, the room temperature would drop and the refrigerant is converted to vapor during the heat absorption process.

Therefore, the fundamental rule of the air conditioner is achieved, in which the temperature is lower than room temperature in the coil inside the room and the temperature is more than the atmospheric temperature in the coil outside the room.

2.2 Thermoelectric module

Unlike the conventional air conditioning systems, the Seebeck effect is a reversible process such that heating and cooling can be obtained on both sides depending on the direction of the current applied to the device. In **Figure 3**, when an electric current is supplied to the device, the electrons and holes will move through the P-type and N-type elements thus causing heating and cooling in the respective sides of the module. These elements are an alloy called Bismuth and Tellurium and when exposed to the same temperature, they have different free electron densities. The P-type element has a deficiency of electrons and the N-type element have an excess of electron and when a current is applied, the module tries to establish an equilibrium and as a result, heating and cooling occurs. Alumina ceramic substrates are used on both sides of the module where the heating occurs in one side and cooling

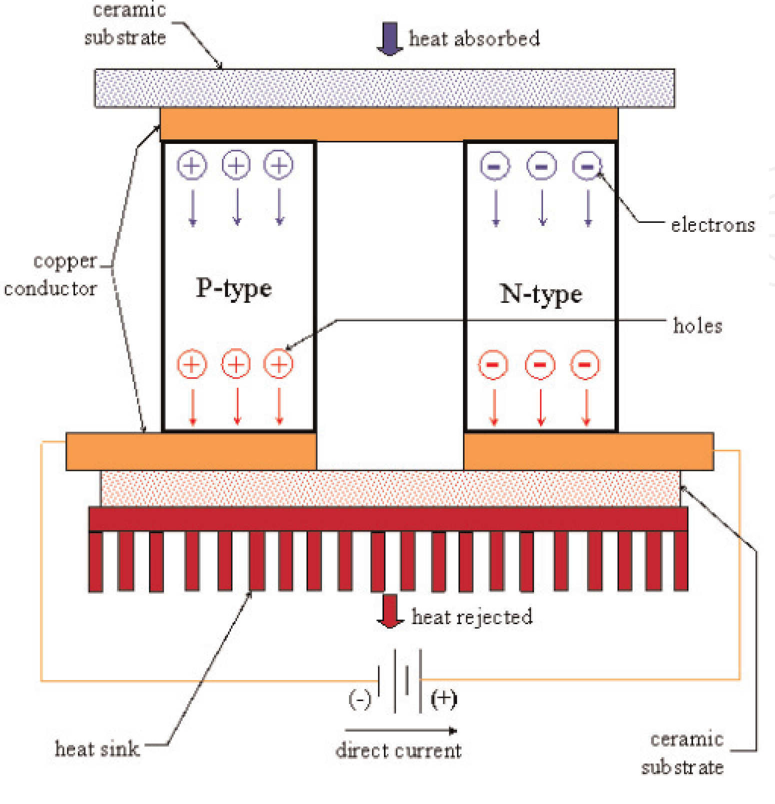


Figure 3.
Principle of thermoelectric module.

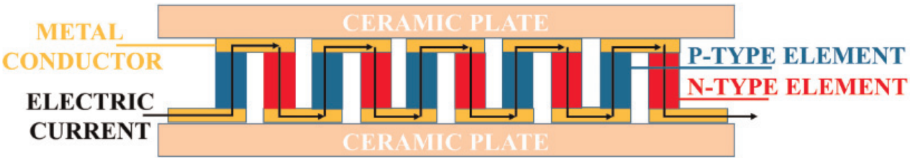


Figure 4.
P-type and N-type elements connected in series.

occurs at the other side. This material is chosen due to being a good insulator of electricity and also being thermally conductive. The coefficient of performance of this device is defined as the ratio of the cooling or heating power to the power supplied to the module.

In order to pump a great amount of heat, the thermoelectric device usually consists of multiple P-type and N-type elements. A typical thermometric device contains around 250 P-type and N-type elements connected in series as shown in in **Figure 4**.

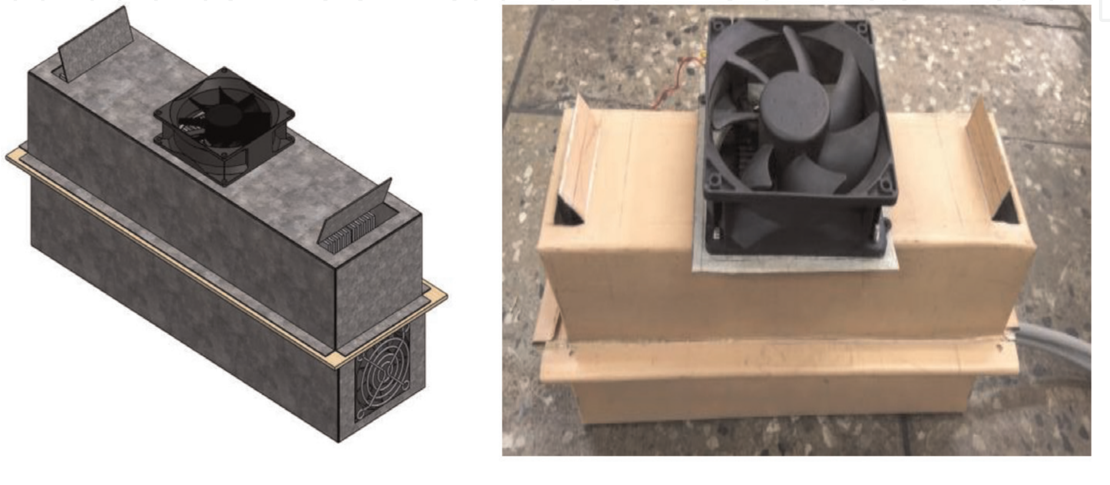
3. Theoretical analysis of thermoelectric air conditioning system

The design of thermoelectric air conditioning system is shown in **Figure 5**, a fan is mounted on top of the cover where air at ambient temperature would be sucked into the device and circulate through the heat sinks and then blow through two rectangular holes such that the direction of the air can be controlled via the flaps. This would allow for the heat from the air to be properly transferred to the heat sinks.

3.1 Determining the cooling load

3.1.1 Cooling and dehumidification of the air

The temperature and relative humidity of the ambient air measured in the laboratory was 31°C and 63% respectively. In order to obtain within thermal comfort range as defined by ASHRAE, it is best to cool and dehumidify the air to 22°C with a relative humidity of 50% as shown in **Figure 6**. The cold side of the thermoelectric module would be at a temperature lower than the dew point temperature and therefore condensation is expected to take place which would decrease the relative humidity of the air [5, 6].



(a) (b)

Figure 5.
Thermoelectric air conditioning system.

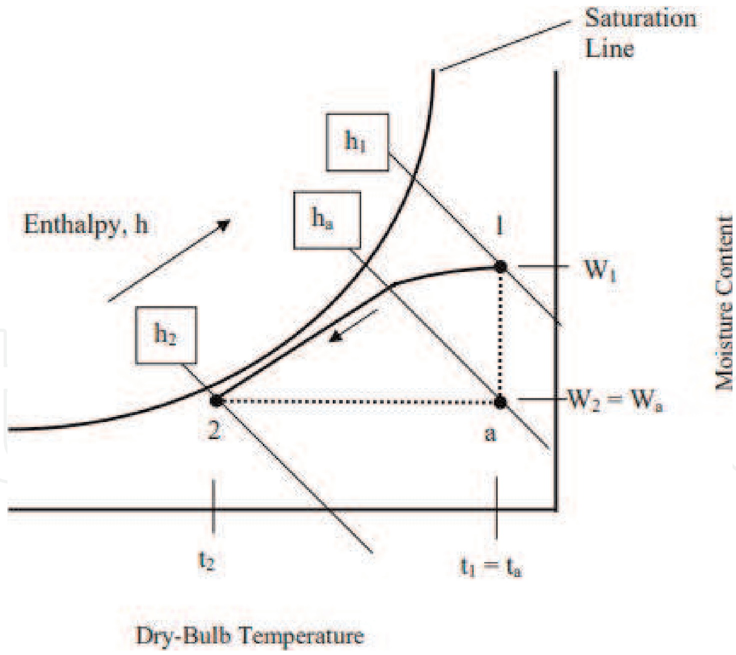


Figure 6.
Psychometric chart: cooling and dehumidifying.

State 1 represents the air properties of the ambient air in the lab while state 2 represents the air properties that we would like to have. The following calculations are used to determine the required cooling capacity for the thermoelectric module.

$$\dot{Q}_T = \dot{Q}_s + \dot{Q}_l \quad (1)$$

$$= \dot{m}_a(h_2 - h_a) + \dot{m}_a(h_a - h_1)h_{f,2} \quad (2)$$

$$= \dot{m}_a\left[(h_1 - h_2) - (W_1 - W_2)h_{f,2}\right] \quad (3)$$

where $\dot{Q}_s$ = sensible heat in kW; $\dot{Q}_l$ = latent heat in kW; h = enthalpy in kJ/kg; $\dot{m}_a$ = mass flow rate in kJ/kg; W = humidity ratio in kg/kg.

At state 1:

31°C, 63% *relative humidity*

$$h_1 = 76.91 \text{ kJ/kg};\ \vartheta_1 = 0.887\text{m}^3/\text{kg};\ W_1 = 0.0179 \text{ kg/kg}$$

At state 2:

22°C, 50% *relative humidity*

$$h_2 = 43.04 \text{ kJ/kg};\ W_2 = 0.0082 \text{ kg/kg};\ h_{\text{f},2} = 83.94 \text{ kJ/kg}$$

A fan of 15 CFM was available at the lab:

15 CFM = 0.00708 m^3/s

$$\dot{m}_a = 0.00708 \text{ m}^3/s \times \frac{1}{0.887\text{m}^3/\text{kg}}$$

$$= 0.00798 \text{ kg/s}$$

$$\dot{Q}_T = \dot{m}_a\left[(h_1 - h_2) - (W_1 - W_2)h_{f,2}\right] \quad (4)$$

$$= 0.00798[(76.91 - 43.04) - (0.0179 - 0.0082)83.94]$$

$$= 0.264 \text{ kW}$$

$$= 264 \text{ W}$$

3.1.2 Sensible cooling load of the enclosure

An enclosure shown in **Figure 7** was designed in order to test the thermoelectric air conditioning system. The enclosure was made of plywood and properly insulated with styrofoam so that the outside temperature would have minimal effect on the testing of the device.

The temperature of the ambient air is 31°C

Thermal comfort temperature is 22°C

Thermal conductivity of wood, $K_{\text{wood}} = 0.151\,\frac{\text{W}}{\text{mK}}$

Thermal conductivity of styrofoam, $K_{\text{styrofoam}} = 0.033\,\frac{\text{W}}{\text{mK}}$

$$R_{\text{Total}} = \frac{L_{\text{wood}}}{K_{\text{wood}}} + \frac{L_{\text{styrofoam}}}{K_{\text{styrofoam}}}$$

$$= \frac{0.01}{0.151} + \frac{0.035}{0.033} \tag{5}$$

$$= 1.13\ \frac{K}{W}$$

Heat transfer through the wall of the box per unit area:

$$q'' = \frac{\Delta T}{R_{total}}$$

$$= \frac{9\ K}{1.13}$$

$$= 7.96\ \frac{\text{W}}{\text{m}^2}$$

$$\text{Area of enclosure} = 2(\ 0.52 \times 0.50) + 2(0.55 \times 0.50) + (0.55 \times 0.50) + (0.57 \times 0.52)\ \text{m}$$

$$= 1.6414\ \text{m}^2$$

Therefore, heat transfer through the wall of the box,

$$\dot{Q} = 7.96 \times 1.6414\ \text{m}^2$$

$$= 13.1\ \text{W}$$

Figure 7.
Enclosure for test of thermoelectric air conditioning system.

3.1.3 Resistor cooling load

A resistor/heating coil was placed in the testing enclosure to observe how long the device takes to remove the heat and maintain a constant temperature. A resistor of 20 W rating was used and the temperature of the enclosure was monitored with time.

3.1.4 Total cooling load required

$$\begin{aligned}\text{Total cooling load} &= \text{cooling/dehumidification} + \text{cooling load of enclosure} + \text{resistor load}\\ &= 264\ \text{W} + 13.1\ W + 20\ \text{W}\\ &= 297.1\ \text{W}\end{aligned} \tag{6}$$

However, the device was sized at a total cooling load of 330 W to take into considerations any additional heat loads that were not accounted for, also the enclosure was not properly sealed.

3.2 Choosing the Peltier module

One of the TEC1-12730 module is capable of producing 250 W of cooling, however in order for one module to produce 250 W of cooling, it needs a dc power supply rated at 30 amps and 18 V. Therefore, by using three modules, a power supply that is available at the lab can be used to supply each module rated at 12 V.

Using three Peltier TEC1-12730 modules:

$$\begin{aligned}\text{Cooling capacity required for each module} &= \frac{330}{3}\\ &= 110\ \text{W}\end{aligned}$$

$$\begin{aligned}\text{Temperature difference}, \Delta T &= T_{hot} - T_{cold}\\ &= 50°\text{C} - 18°\text{C}\\ &= 32°\text{C}\end{aligned}$$

The specification graphs for the TEC1-12730 module shown in **Figures 8** and **9** were used in determining the appropriate amperage and voltage needed to supply each thermoelectric module.

At $\dot{Q}_c$ = 110 W and ΔT = 32°C, amperage, I = 21 amps
Using the second graph to determine the voltage to apply:
Using 21 amps and ΔT = 32°C, therefore V = 12 V
Power consumed by the three (3) Peltier device = $3 \times (12 \times 21) = 756$ W

3.3 Sizing the heat sink

Determining the thermal resistance of a required heat sink (**Figure 10**) for the hot side of each thermoelectric module:

Maximum operating temperature of the thermoelectric module: 138°*C* [7].
Thermal resistance of the heat sink needed,

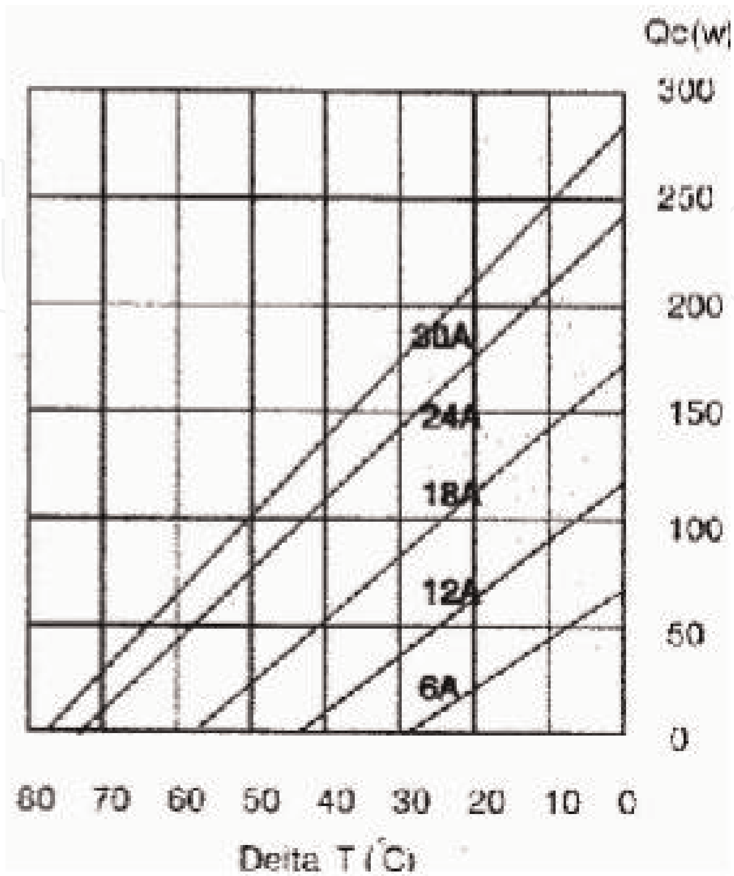


Figure 8.
Specification graph 1 for the TEC1-12730 module.

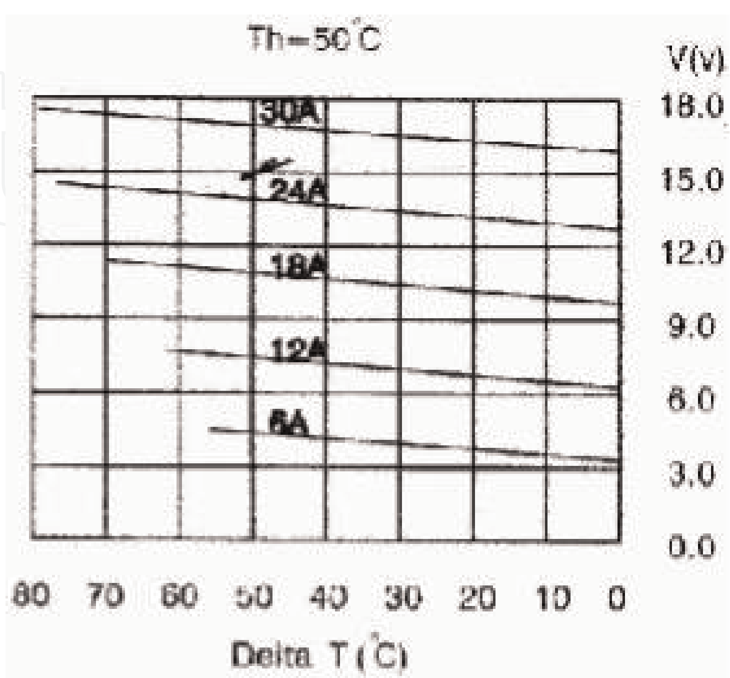


Figure 9.
Specification graph 2 for the TEC1-12730 module.

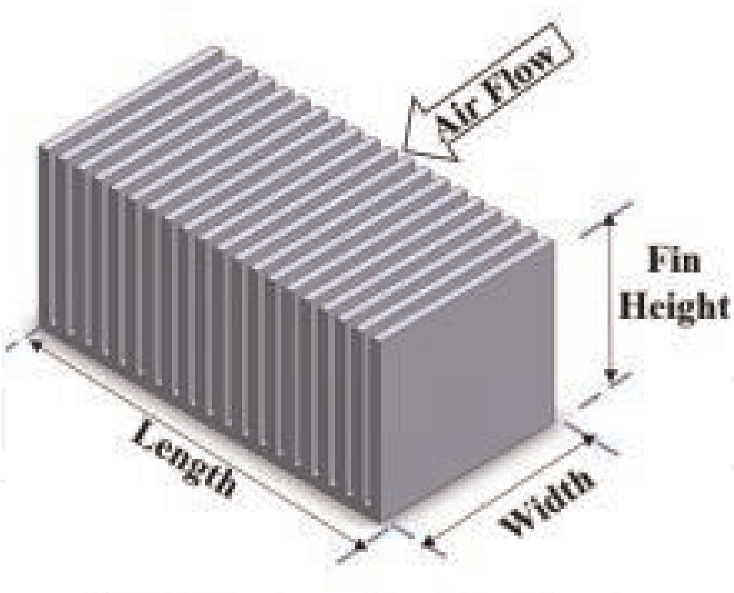


Figure 10.
Sizing the heat sink.

$$R_{hs} = \frac{T_{hot} - T_{amb}}{\dot{Q}_{T,1} + P_{peltier}} = \frac{138 - 31}{362} = 0.296\ \frac{K}{W}$$

Air flow of fan used for heat sink, ϑ = 0.142 $m^3 s^{-1}$ (CFM of fan available at lab = 300)
Width of heat sink, W = 0.08 m
Width of the fin, L = 0.064 m
Thickness of fin, t_{fin} = 0.0015 m
Number of fins, N_{fin} = 20
Height of fin, H_f = 0.057 m
Height of heat sink, H = 0.069 m
Spacing between the fins [8],

$$b = \frac{W - (N_{fin} \times t_{fin})}{N_{fin} - 1} = \frac{0.08 - (20 \times 0.0015)}{20 - 1} = 0.003\ \text{m}$$

Velocity of air between the fins,

$$\text{V} = \frac{\vartheta}{N_{fin} \times b \times H_f} = \frac{0.142}{20 \times 0.003 \times 0.057} = 41.52\ \text{ms}^{-1}$$

The properties of air at one (1) atmosphere and 31°C are as follows:
Density, $\rho = 1.15 \frac{kg}{m^3}$
Specific heat capacity, $Cp = 1.007 \frac{kJ}{kg.K}$
Dynamic viscosity, $\mu = 18.718 \times 10^{-6} \frac{N.s}{m^2}$
Heat conductance, $K = 26.424 \times 10^{-6} \frac{kW}{m.K}$
Prandtl number,

$$\begin{aligned} Pr &= \frac{\mu \times C_p}{k} \\ &= \frac{18.718 \times 10^{-6} \times 1.007}{26.424 \times 10^{-6}} \\ &= 0.713 \end{aligned}$$

Reynolds number,

$$\begin{aligned} Re &= \frac{\rho \times V \times b}{\mu} \times \frac{b}{L} \\ &= \frac{1.15 \times 41.52 \times 0.003}{18.718 \times 10^{-6}} \times \frac{0.003}{0.064} \\ &= 358.72 \end{aligned}$$

Nusselt number,

$$\begin{aligned} Nu &= \left[\frac{1}{\left(\frac{Re \times Pr}{2}\right)^3} + \frac{1}{\left(0.664\sqrt{Re}Pr^{0.33}\sqrt{1+\frac{3.65}{\sqrt{Re}}}\right)^3} \right]^{\frac{-1}{3}} \\ &= \left[\frac{1}{\left(\frac{358.72 \times 0.713}{2}\right)^3} + \frac{1}{\left(0.664\sqrt{358.72}0.713^{0.33}\sqrt{1+\frac{3.65}{\sqrt{358.72}}}\right)^3} \right]^{\frac{-1}{3}} \\ &= 12.28 \end{aligned}$$

Heat transfer coefficient,

$$\begin{aligned} h &= Nu \times \frac{k}{b} \\ &= 12.28 \times \frac{26.424 \times 10^{-3}}{0.003} \\ &= 108.16 \end{aligned}$$

Efficiency of the fin,

$$\begin{aligned} \eta_{fin} &= \frac{\tanh\left(m \times H_f\right)}{m \times H_f} \\ &= \frac{\tanh(29.39 \times 0.057)}{29.39 \times 0.057} \\ &= 0.556 \end{aligned}$$

$$m = \sqrt{\frac{2h}{k_{fin} \times t_{fin}}}$$

$$= \sqrt{\frac{2\,x\,108.16}{167 \times 0.0015}}$$

$$= 29.39$$

Surface area of the exposed base,

$$A_{base} = \left(N_{fin} - 1\right) b \times L$$

$$= (20 - 1)0.003 \times 0.064$$

$$= 0.00365 \text{ m}^2$$

Area of the fin,

$$A_{fin} = 2 \times H_f \times L$$

$$= 2 \times 0.057 \times 0.064$$

$$= 0.0073 \text{ m}^2$$

Thermal resistance of the heat sink,

$$R_{hs} = \frac{1}{h.\left(A_{base} + \left(N_{fin}\eta_{fin}A_{fin}\right)\right)}$$

$$= \frac{1}{108.16.(0.00365 + (20 \times 0.556 \times 0.0073))}$$

$$= 0.109 \frac{\text{K}}{\text{W}}$$

$0.109 \frac{\text{K}}{\text{W}} < 0.296 \frac{\text{K}}{\text{W}}$, since the calculated thermal resistance of the heat sink available is less than the required thermal resistance of the heat sink then therefore, this heat sink was used.

4. Experimentation of the thermoelectric air conditioning system

4.1 Apparatus

- Thermocouples
- 12 channel thermocouple data recorder
- Power supply
- Multi-meter
- Power strip

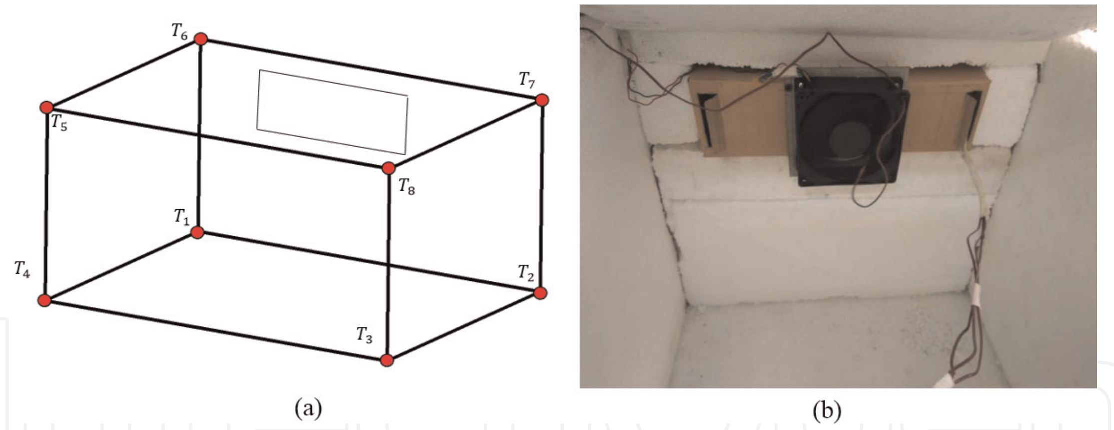


Figure 11.
Testing enclosure showing points at which temperature were taken.

Figure 12.
Thermoelectric air conditioner placed inside of testing enclosure.

4.2 Method/procedure

i. The thermoelectric air conditioning system was connected to the power supply and connected to the power trip.

ii. The thermocouples were connected to the 12-Channel Thermometer and the location of the thermocouples was noted as shown in **Figure 11**.

iii. The power strip was turned on which simultaneously powered on the thermocouple data recorder and the thermoelectric air-conditioner as shown in **Figure 12** and **Table 1**.

5. Results and discussion

From the graph of temperature (°C) versus time (min) as shown in **Figure 13**, an exponential decay curve was obtained. The graph was linear in the first 3 min and the thermoelectric air conditioner minimum temperature for that time was 22.3°C. For no heat load, the thermoelectric air conditioner was able to cool the enclosure to the desired thermal comfort temperature of 22°C in 6 min. A typical air conditioning system that operates on the refrigeration cycle takes approximately 30 min to cool a room to the thermal comfort temperature of 22°C [9, 10].

Time (min)	Ambient temperate (°C)	Temperature inside enclosure (°C)							
		T1	T2	T3	T4	T5	T6	T7	T8
0	30.5	30.7	30.9	30.8	30.7	30.9	29.7	29.9	31.2
1	31.0	28.2	28.1	28.0	28.1	27.1	27.5	27.1	27.2
2	31.2	26.1	26.1	25.9	26.3	24.8	27.2	26.3	25.5
3	30.0	23.5	23.5	23.4	23.5	22.3	25.1	24.3	23.2
4	31.0	21.7	21.9	21.9	21.9	20.7	24.0	23.5	21.8
5	30.8	20.5	20.7	20.6	20.6	19.6	23.0	22.5	20.6
6	30.0	19.7	19.9	20.0	19.9	18.9	22.4	21.6	20.0
7	31.0	18.4	18.7	18.8	18.6	17.8	21.3	20.4	18.9
8	31.0	18.0	18.2	18.3	18.1	17.3	20.9	20.0	18.5
9	31.0	17.8	18.1	18.2	18.0	17.1	20.1	19.3	18.3
10	31.0	17.6	17.9	18.0	17.7	16.9	20.0	18.8	18.1
11	30.6	17.4	17.7	17.9	17.5	16.7	18.9	18.1	18.0
12	30.6	17.2	17.4	17.5	17.2	16.4	18.7	18.1	17.7
13	30.8	17.4	17.7	17.8	17.4	16.6	18.9	18.2	17.9
14	30.5	17.2	17.6	17.6	17.4	16.5	18.8	18.0	17.7
15	31.0	17.0	17.2	17.3	17.2	16.5	18.6	17.8	17.6
16	31.1	16.7	16.9	17.3	16.7	16.6	18.3	17.5	17.1
17	30.9	16.4	16.8	16.6	16.5	16.5	17.7	17.2	17.1
18	30.9	16.4	16.9	16.7	16.5	16.4	17.7	16.8	16.9
19	30.5	16.5	16.6	16.6	16.5	16.3	17.5	16.7	17.0
20	30.6	16.4	16.5	16.6	16.7	16.3	17.2	16.6	16.9
21	31.0	16.5	16.4	16.6	16.5	16.3	17.1	16.7	16.8
22	30.5	16.5	16.4	16.6	16.4	16.2	16.8	16.6	16.8
23	29.8	16.4	16.5	16.7	16.4	16.3	16.6	16.5	16.7

Table 1.
Temperature readings obtained from testing enclosure of thermoelectric air conditioner.

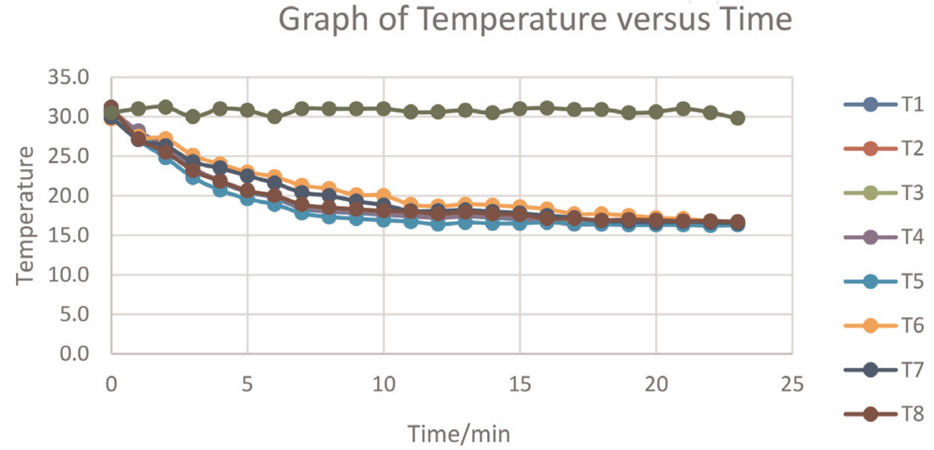


Figure 13.
Graph of temperature/°C versus time/min.

Therefore, the thermoelectric air conditioner has a much faster cooling rate as compared to the conventional air conditioning system. The thermometric device was able to cool the enclosure and maintain a minimum temperature of 26.5°C, however it was expected that the device would cool the enclosure much less than this temperature. This was limited to the high temperature on the hot side of the module. The temperature on the hot side of the thermometric module was stable at 39.6°C when the minimum temperature of the enclosure was 26.5°C. From the specification graph of the module, the temperature difference chosen was 30°C. Therefore, if the hot side of the module was maintained at a much lower temperature then the cold side of module would result in a lower temperature reading (**Tables 2** and **3**).

Specific volume at inlet, $\vartheta_1 = 0.882 \frac{m^3}{kg}$

15 CFM fan used = $0.00708 \frac{m^3}{s}$

Mass flow rate, $m_a = 0.00708 \frac{m^3}{s} \times \frac{1}{0.882 \frac{m^3}{kg}}$

Mass flow rate, $m_a = 0.008027 \frac{kg}{s}$

Using a psychometric chart, the enthalpy was determined for both the inlet and outlet of the thermoelectric air conditioning unit.

Enthalpy of the air at the inlet, $h_i = 71.2 \frac{kJ}{kg}$

Enthalpy of the air at the outlet, $h_o = 35.6 \frac{kJ}{kg}$

Difference in enthalpy,

$$h_d = h_i - h_o$$

$$= 71.2\text{–}35.6$$

$$= 35.6 \ \frac{kJ}{kg}$$

Thermoelectric module	Voltage (V)	Current (A)	Power (W)
Module 1	11.85	18.11	214.60
Module 2	11.79	17.61	207.62
Module 3	11.96	17.32	207.15

Table 2.
Voltage and current readings obtained from the multi-meter.

No.	Inlet air temperature (°C)		Outlet air temperature (°C)		Power (W)
	Dry bulb	Relative humidity %	Dry bulb	Relative humidity %	
1	30.7	60.6	17.1	52.1	614.25
2	28.1	60.9	18.8	54.2	617.10
3	31.5	59.7	16.9	54.8	613.98
Average	30.1	60.4	17.6	53.7	615.11

Table 3.
Experimental results of thermal properties of thermoelectric air-conditioner.

Cooling capacity of the unit,

$$\begin{aligned}\dot{Q}_{cc} &= \dot{m}_a(h_i - h_o) \\ &= 0.008027\ \frac{\text{kg}}{\text{s}} \times 35.6\ \frac{\text{kJ}}{\text{kg}} \\ &= 0.286\ \text{kW} \\ &= 286\ \text{W}\end{aligned}$$

Coefficient of performance,

$$\begin{aligned}\text{C.O.P.} &= \frac{\dot{Q}_{cc}}{P_{in}} \\ &= \frac{0.286}{0.61511} \\ &= 0.465\end{aligned}$$

In comparing the owning and operating costs of the thermoelectric air conditioner to an air conditioner that operates using the refrigeration cycle, the thermoelectric air conditioner was the better choice of approximately 47.5% cheaper in the overall costs. Although the overall cost of the thermoelectric air conditioner was cheaper, it consumes a considerable large amount of power of 695 W more. This resulted in a higher cost of electricity per year of $156.12 more than the refrigeration air conditioner.

However, the major factors which influenced the thermoelectric air conditioner in being the overall cheaper choice are the; life span of the device and the operating costs. The thermoelectric air conditioner has a greater estimated life span of 7 years more than the refrigeration air conditioner. This is because the life span of the air conditioner that operates on the refrigeration cycle uses a compressor which is the "heart" of that air conditioning system, contains a lot of moving parts and is therefore more prone to failure. On the other hand, the thermoelectric air conditioner uses thermometric module which is the main component of the system, contains no moving parts. Maintenance of the thermometric air conditioner is also cheaper in which it does not need re-gassing or regular inspection check for gas leaks as compared to the refrigeration air conditioning system.

The coefficient of performance was calculated for the thermoelectric air conditioning system, which was found to be 0.465. This value is small in comparison with the average coefficient of performance for the vapor refrigeration cycle of 3.0 [11, 12]. The main reason for this vast difference is the power consumption of the thermoelectric air conditioner. The experimental cooling capacity was found to be 286 W while the system was sized for 330 W. In comparison, this value showed a 13.1% reduction of cooling capacity which may be due to the power supply used to power the thermoelectric air conditioner, since the system was only consuming 615.11 W while it was calculated that the system needed 756 W in order to produce a cooling capacity of 330 W. Additional causes may be inaccuracies in the experiment or heat leaks between the cold and hot side of the thermoelectric module.

6. Conclusion

A prototype of a thermoelectric air conditioner was designed. Designed calculations were produced. The hot side of the module did not exceed the maximum operating temperature of 138°C, which means that the design of the heat sink for the hot side was sufficient. In additionally, CFM rating for the exhaust fans were calculated which led to the proper selection of the fans to be used. The prototype of the thermoelectric air conditioner was successfully built and tested. From the design calculations, the appropriate materials for the device were selected which enabled the device to cool and dehumidify to the thermal comfort zone. The performance of the prototype was determined where:

i. A cost analysis was done in which the thermoelectric air conditioner was compared to a conventional air conditioner that operates based on the refrigeration cycle and the thermoelectric air conditioner was the better choice with an overall 47.5% cheaper in overall cost.

ii. The coefficient of performance of the system was calculated and found to be 0.465.

iii. The device was able to cool and dehumidify the air within the thermal comfort zone of 22°C and 53.7% relative humidity.

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