

Evaluation of a Different Model of Affordable Eco Cooler Using Thermoelectric Module and Joule Thomson Effect and Its Social Aspects

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ABSTRACT

Researchers have lately shown an interest in developing piezoelectric technology as a particularly noble cooling method definitely due to its obvious benefits over compression refrigeration methods like the absence of a compressor, refrigerator, moving parts, and other components. However, very few models of these types of air coolers kind of have been tested so far. This research particularly focuses on a unique thermoelectric air cooler model, including the Joule Thomson effect of air. The objective of this research is to provide an affordable cooling solution for the lower-income people living in slums and mountainous regions where the supply of enough electricity is a big issue. To produce the Joule Thomson effect, a cone-shaped physical model constructed of Polylactic acid was 3D printed, and six Peltier modules were positioned radially to strain the Thermoelectric effect and a forced draft fan is used to supply the required air with very high velocity and pressure. This product will not only be cost-efficient but also will be environmentally friendly. The social acceptance of this kind of cooler mostly has been quite a large issue also. Thus, a survey has been conducted on 50 middle-class to really poor people of Mirpur 11 (Parise Road slums) and Vashantek where the importance of this kind of cooler has particularly become. Around 76% of them found it useful and generally were very kind of interested in it being set in their houses, which is quite significant. However, a presence of doubt in the mind of basically many people about the lifespan of this product sustains.

Keywords: Thermoelectricity, Peltier, Joule Thomson, Eco-Cooler, Survey

1. Introduction

Because of the increasing demand for power and the diminishing fuel supply, scientists and researchers are working around the clock to find a solution to the energy crisis. Up until a new, renewable source is discovered, energy must be used wisely and effectively. The idea of "energy efficiency" was born out of this one [1]. Lowering a nation's overall annual energy use, however, requires more than improving energy efficiency. Therefore, scientists have been working to create mechanically propelled gadgets that need little or no electricity for quite some time. The energy usage of the air conditioning system is one of the highest. Energy for air conditioning systems is becoming an increasingly pressing issue in emerging nations and this demand is growing quickly along with income growth.

The average temperature is rising day by day, which has caused a dramatic change in the worldwide climate. People's daily life has been severely impacted by the consequences of global warming. The global average temperature is increasing at a pace of 0.8°C per decade in the modern world, where climate change is becoming unavoidable [2]. In the past 15 years, 13 of the top 15 hottest years on record have occurred. The most recent decade was also the hottest. The temperature change trend is quite unsettling, according to statistics, especially for India alone. The country of India's annual mean temperature is rising quickly. If the current trend continues over the following ten years, it will surpass the 1.5°C level. According to records, 2016 was the hottest

year ever. There is a rise in temperature of 1°C each century even during the monsoon season. The study found that for a suitable living environment, the outside temperature should be between 22 and 24 degrees Celsius. But with the recent sharp rise in temperatures, it is essential to offer a low-cost and efficient method of lowering interior temperatures while keeping the sustainability concept in mind.

According to studies, by the year 2030, several major cities in emerging nations may see a significant rise in the yearly energy consumption for air conditioning systems [3]. Due to climatic conditions, air conditioning systems must be used even in several middle-income nations in Middle East Asia. Zero-power usage coolers have been developed as a result of all these factors. One such invention is alleged to be the eco-cooler.

Ashis Paul, a worker at Grameen Intel, came up with the idea, and Grey Group, a business in New York, USA, produced the product specifically for third-world nations [4]. It is built from recycled pet bottles and is advertised as having the ability to reduce room temperature by up to 5.0 degrees Celsius without using any power. In this paper, the veracity of this assertion is examined. The novel and ground-breaking cooler, according to its creator, operates on the "Joule-Thomson effect," a well-known phenomenon in classical physics [5]. However, the Joule-Thomson effect is visible when gas flows at a high velocity through a tiny hole and there is a significant pressure gradient. As a result, the gas's temperature

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reduces and, in certain situations, it turns into liquid. As a result of this temperature reduction, the components of air become liquid. However, because of the minimal pressure gradient across the cooler, this is not the case with the eco-cooler (10-800 Pa) [6]. As a result, it is challenging to compare the Joule-Thomson effect with the eco-operating cooler's principle. It nonetheless complies with the rules of compressible fluid flow, according to which the temperature of the fluid falls as it passes through a convergent nozzle. Therefore, it is anticipated that the usage of an eco-cooler may result in a temperature reduction, but it may not be as great as that seen in the usual uses of the Joule-Thomson effect.

In this study, the usefulness of an eco-cooler in drastically decreasing temperature is investigated using experimental approach. The increase in air velocity near the outflow is also evaluated in this experiment. While there are papers regarding eco-cooler and coolers with thermoelectric modules separately, but none of them stated the effects of them together. A comfortable living room climate may be produced by employing an updated eco-cooler, a low-cost and ecologically friendly appliance made of non-biodegradable plastic, a Peltier thermoelectric module, and the Joule Thomson and Seebeck effects.

This thermoelectric assembly's construction's underlying technology is known as "The Peltier Effect." It uses two layers of a semiconductor made of bismuth telluride that has been doped. These devices produce a cooling action when a direct current (DC) power supply is applied, which is offset by the creation of heat on the opposing side of the device. This idea underlies eco coolers, which eliminate the need for a compressor, high cost, and ozone-depleting CFCs [7]. Studies showed that by using the Peltier module air conditioning is possible and temperature can be reduced by up to 23% by only using solar energy [8-9]. This research focuses on the unusual design of this Peltier air cooling system, which also employs the Joule-Thomson effect. For the acceptance of this type of air conditioning in the poor community, a survey has also been conducted.

2. Methodology

2.1 Experimental Setup

For this study, two cone-shaped structures have been created by 3D printing. Fig 1. illustrates the complete setup of the device with S1 and S2, the two cone-shaped structures. The longer structure S1 is 14inch long with a bigger diameter of 12 inches and a smaller diameter of 6 inches whereas S2 is only 7 inches long with diameters of 10 inches and 7 inches respectively. Both structures are of the same thickness of 0.5 inches but plane C in fig.1 is 1.5 inches thick with several cone-shaped holes cut through it. These holes increase the velocity and pressure of the inner air which flows due to the forced draft fan attached to plane A. For this research, a table fan has been used of 12 inches diameter and 60-220V power rating with 1500-2500 rpm. Plane B is situated

between planes A and C and 4 inches offset from plane C where all the Peltiers modules have been installed on the wall of S1 with the cooler sides of the modules facing inwards. A copper wire gaze is placed between the Peltiers connecting all the Peltiers to ensure convective heat transfer all over that circular plane. The hotter surfaces of the modules are cooled by redirecting a portion of the cold air to the hot surfaces of the modules and ejecting it outside. The small gap between the walls of structures S1 and S2 ensures proper and well-directed air flow toward the hot surfaces. Temperatures of the inner air and outer air have been taken by a K-type thermocouple [10]. The Peltier modules had ratings of 6V. The modules have been turned on and off individually to get the temperature changes with 3 to 6 Peltiers turned on while all the Peltiers were turned off to get the Joule Thomson effect. Polylactic acid (PLA) has been used for the whole 3D printing process.

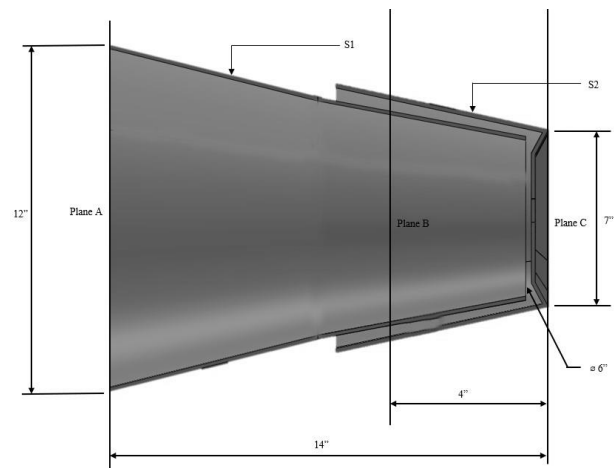


Fig. 1 Cross section of the experimental setup.

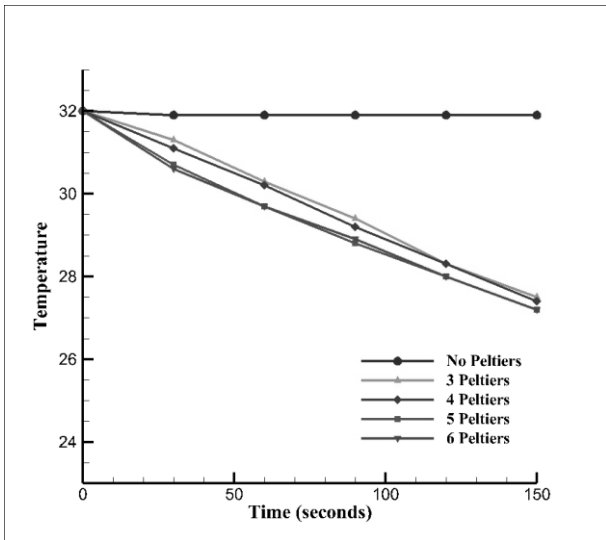
2.2 Survey Method

Social acceptance of any product is no less important than its technical success. To assess the need and acceptance of these kinds of products in the market, a questionnaire survey was conducted. The questions had 2 sections. The first set of questions was related to the personal information of the correspondents. The second set of questions was related to their electricity insufficiency-related problems. This survey was conducted in the slums of Parise Road, Mirpur, and Shyamal Polli, Vashantek. As the potential customer of this product will be the low-income community, these areas were selected for this research. A total of 50 individual samples were collected and later a detailed FGD was conducted with the local community.

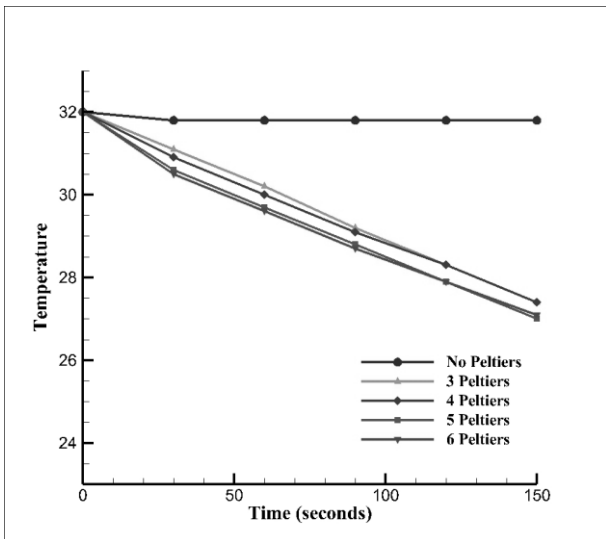
6. Results and discussion

In this study, the concept of the Joule-Thomson Effect is used. When a real gas or liquid is forced through a valve or porous plug and the system is insulated to not exchange heat with the environment, then the temperature of the real gas or liquid is changed. This process is also called the Throttling process or the Joule

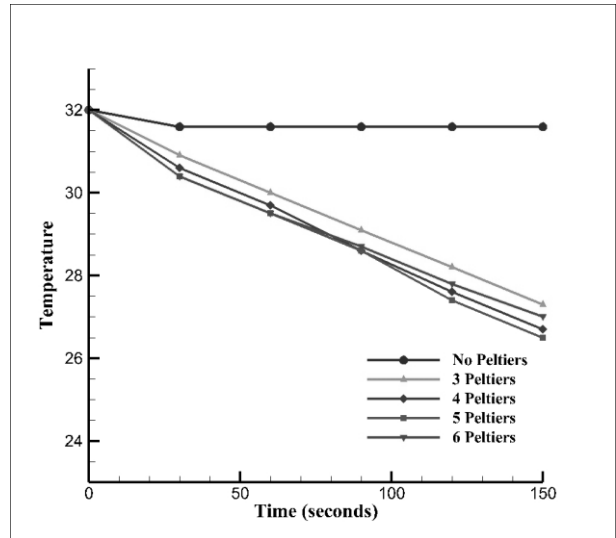
Thomson process. Almost all real gases cool upon expansion by the Joule-Thomson Effect. In this eco cooler, for creating the throttling process a cone-shaped structure is used in which the diameter of the structure is continuously decreasing. At the end of the structure, there are porous plugs through which air can flow. We know the pressure is increasing with increasing velocity. For different speeds of the fan, we measure the inlet and outlet temperatures and all the Peltier modules are turned off. From Fig. 2(a), (b), and (c), we can see that the temperature of the outlet air is slightly less (about 0.5°C) than the inlet air. The main reason for this slight increase in temperature is that the speeds used in the experiment it can't create much pressure difference between the inside and outside of the structure.



(a)



(b)

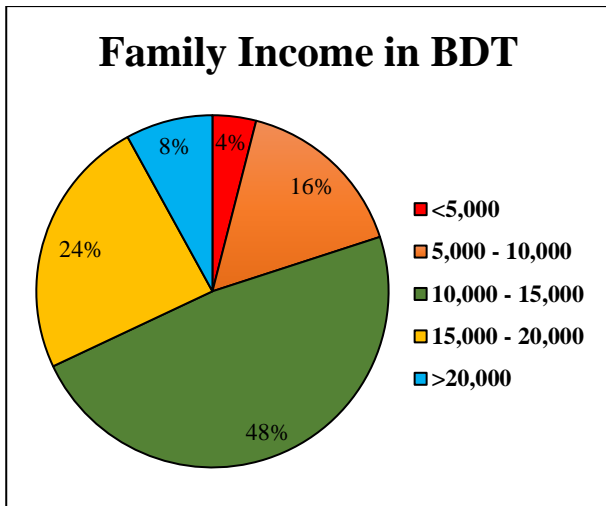


(c)

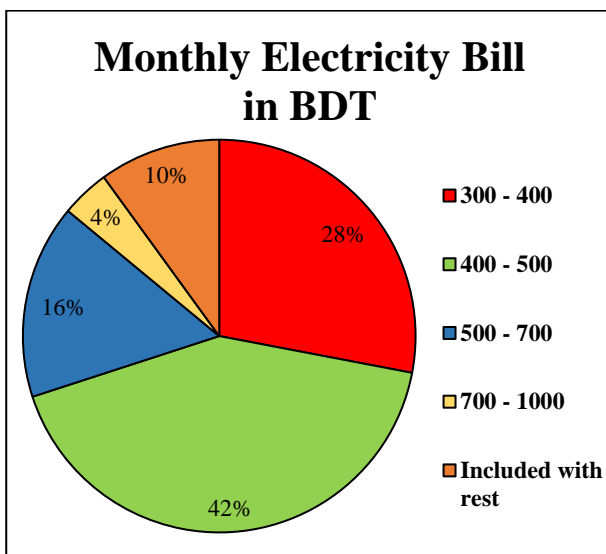
Fig 2. (a), (b), and (c) illustrates the variation of temperature with time and the number of Peltier Modules being used at a fan speed of 1500 rpm, 2000 rpm, and 2500 rpm respectively.

Peltier modules are also used in this study inside the cone-shaped structure. Peltier modules (Thermoelectric modules) is a thermal control module that has both warming and cooling effects. The cooling effect of the structure with different combinations of Peltier modules turned on is observed. From the graphs, it is observed that the outlet air temperature is decreasing with the increasing number of Peltier modules turned on. As the number of Peltier modules increases the cooling surface is increasing. As a result, the outlet air temperature also decreases. But it is also observed that in the case of turning on 5 and 6 Peltier modules, the cooling effect is almost the same. So, it can be said that using 5 Peltier modules is more efficient than using 3,4, or 6 active Peltier modules.

The questionnaire survey was conducted to check the social acceptance of this product. The first set of questions had results that included their personal information such as gender, monthly income, household head, etc. Among the samples, 64% of them were male and 36% of them were female. The people of these areas are very poor. Around 48% of people live in a family where the family income is between 10,000 to 15,000 BDT. Even 4% of people live in a condition where the family has no stable income or the income is below 5000 BDT. A major portion of people lives under the poverty line. Almost everyone lives in rented single rooms where they use a single toilet per 5-6 households. The results are presented graphically below.



(a)



(b)

Fig 3. (a), and (b) show some of the results graphically.

The results show that poverty has crushed the people of this region and the electricity bill is costing them a lot. They are pretty willing to adapt to new technologies if it costs less energy. As they understand the fact that less energy consumption will cost them fewer electricity bills. Around 76% of the samples were willing to adopt this new technology. 18% of them were a bit hesitant about it but they are willing if it is implemented by the Government or some NGO. The rest of the 6% of people are unwilling to adopt this technology even if it is going to cost them fewer electricity bills. These results show the impact and necessity of these types of products in the market and how this can benefit the low-income community of this country in the long run. However, the longevity of this product is also a concern to them.

4. Conclusions

Air cooling by the Joule-Thomson effect could not meet human satisfaction, but alongside Peltier Thermoelectric Module it has created an acceptable

temperature difference. With the increase of air velocity and the number of Peltier being used a significant increase in the temperature difference is observed. But this increasing trend declines after using more than five Peltiers as the radiation of the heating part hinders the cooling process. Though the result of the questionnaire survey was pretty positive, the longevity of this product is definitely an important issue in this case which to some extent, this product has failed to meet.

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