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An Experimental Study of Sustainable Cooling using Peltier Effect

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***Abstract*- In the era of globalization and action on climate change had raised concern for upcoming environmental issue. The various studies show that it is due to petroleum product and thermal power plant, but the majority of power required is for application of heating (Warm water/ Cooking) or cooling (water Chiller/refrigeration/air-conditioner). This cooling device also has lot of mechanical parts and the leakage of refrigerant is major concern. The experiment illustrated in this research paper has a wide arrangement of device called TEC (Thermo-electric couple), where electron we have as a refrigerant fluid to carry out the heat from the system.**

Keywords—TEC (Thermo-Electric Couple), Renewable Energy, Peltier effect, thermal Conductivity

I. INTRODUCTION

1.1 PRESENT SCENARIO

Nowadays, thermoelectric technology has wide application in commercial as well as domestic sectors such as high-quality temperature control, such as precision instruments for medicine and research. Dehumidifiers and air conditioners for domestic and automotive sectors are future of tomorrow due to portability, low power consumption, durability and economically viable solution as compared to conventional devices [1].

1.2 TEC (THERMO-ELECTRIC COUPLER)

Thermoelectric refrigeration offers several advantages with respect to conventional vapour compression technology, since thermoelectric devices are more compact, free of noises and vibrations, provide high-quality temperature control and require far less maintenance [2]. These significant facts led to the development of original and interesting thermoelectric refrigeration devices, subsequently released into the market [3].

Coefficient of performance (COP) of thermoelectric refrigerators, on the other hand, is significantly lower than that of vapour compression based devices, which explains the fact that vapour compression technology predominates in both industrial and domestic refrigeration markets. However, one of the main disadvantages of vapour compression based refrigerators lies on the oscillatory pattern of the inner temperature, caused by the characteristic stop and start cycles of the compressor [4].

This impact prompts extremely critical oscillations in the temperature of the air encased in the refrigeration compartment, which intensifies, all things considered, the preservation of sustenance or transitory merchandise [5].

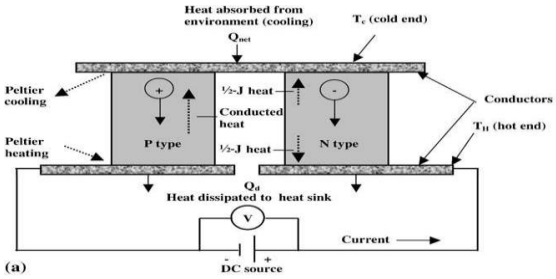

Figure 1: Typical Diagram of Peltier Effect

II. EXPERIMENT

1.3 THEORETICAL PRINCIPLE FOR TEC

TEGs can be put to use in different vitality change applications, from wristwatches to vehicles, since their yield power can be in the range from a few µW to kW. Specifically, thermoelectric profit by low to medium power measure applications, while other change frameworks (counting force plants) become less proficient as they are downsized in size and power [6]. They are along these lines of enthusiasm for use in low to medium power applications. Taking force applications, outstandingly those utilized in huge numbers. Accepting the human body, for instance, it is additionally a warm source losing heat by convection, conduction, and radiation.

1.4 EXPERIMENTAL SETUP:

The experimental work comprises of a shut volume of 0.08m3 incorporated with Peltier Kit. The shut volume body is made of Polyurethane [7], So as to limit the heat loss from the shut volume it is all around protected with the assistance of Aluminum foil and Poly-Urethane Foam is utilized as building material since thermal conductivity of PUF is low (0.021W/MK) which will further decrease the heat misfortune also divider thickness of 3mm is kept in order to limit heat misfortune. Assumptions made during the fabrication of experimental setup.

A. No heat loss takes place from or to the system.
B. Thermo-physical properties such as Resistivity, conductivity etc does not change with temperature.
C. Heat transfer takes place only through the P-type and N-type semiconductor.
D. The elements are thermally and electrically insulated

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from their surrounding except at the junction reservoir contact and the temperature distribution inside the element may be described by a One Dimensional heat Conduction problem.

II. EXPERIMENTAL ELEMENTS

2.2.1 PELTIER ELEMENT

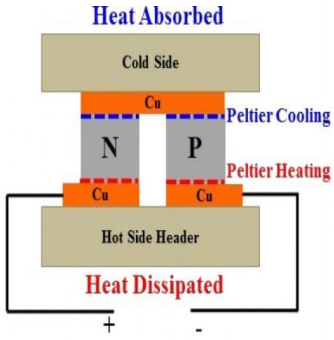

Figure 2 PN Junction and Typical Thermoelectric Module

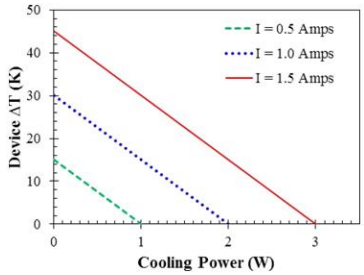

Figure 3 Performance curve of the thermoelectric device

2.2.1.1 FEATURES OF TEC1-12706

1. Small module
2. Operable up to 138°C
3. Easy progress between the hot side to the cool side and the other way around just by switching the extremity of supply.
4. Quality tried cooling cells.
5. Solid-state, vibration-free, clamour free.

2.2.1.2 SPECIFICATIONS

Table 1 Specifications of Peltier Element

MODEL	Unit	TEC1-12706
Operating Voltage	(VDC)	12
Maximum Voltage	(V)	15
Maximum Current	(A)	6.4
Maximum Power	(W)	92
Maximum Temperature	(°C)	200
Melting Point of Internal Solder	(°C)	235
Internal Resistance	(Ω)	1.98
Wire Length	(mm)	200
Length	(mm)	40
Width	(mm)	40
Height	(mm)	36
Weight	(gm)	30
Maximum Compressive Load	(MPa)	1

2.2.2 SWITCH MODE POWER SUPPLY

A Switch Mode Power Supply is an electronic power supply that joins a switching controller to change over electrical power productively. Like other power supplies, an SMPS moves powers from a DC or AC source (frequently mains power) to DC loads, for example, a Personal Computer. Not at all like a direct power supply, the pass transistor of a switching-mode supply ceaselessly switches between low dissemination full on and full off states, and invests next to no time in the high scattering changes, which limits squandered vitality [8]. In a perfect world Switch Mode Power supply disperses no power. Voltage guideline is accomplished by fluctuating the proportion of on to off time(also known as obligation cycles). Interestingly, a straight power supply manages the yield voltage by constantly dispersing power in the pass transistor. This powerful transformation proficiency is a significant favourable position of switch-mode power supply. A Switch Mode Power Supply may likewise be significantly littler and lighter than a straight supply because of the little transformer size and weight [9].

2.2.2.1 Specifications of SMPS

Table 2 Specifications of SMPS

Table 2: SMPS SPECIFICATION

Property	Values
Input Voltage	AC 100 - 264V 50 / 60Hz
Output Voltage	12V DC, 10A
Output Voltage: Adjustment Range: 20%	
Protections: Overload/Overvoltage/Short Circuit.	
Cooling by free air convection.	
LED Power supply with a metal body for hidden installation for LED lighting.	
Design with built-in EMI filter, improve signal precision.	
Meantime between failure 500000 Hours	
Output Type-DC	
Output-12Volts 10Ampere	
Operating Humidity:20% to 80%	
Power conversion Efficiency:80%	
SMPS Weight 625Grams	
Dimensions:200*98*40mm	

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Figure 4 SMPS used in the experimental setup

2.2.3 HEAT SINK

A Heat Sink is a detached heat exchanger that moves the heat produced by an electronic or a mechanical gadget to a liquid medium, regularly air or a fluid coolant, where it is dispersed far from the gadget, in this manner permitting guideline of the gadget's temperature at ideal levels [10]. In PCs, heat sinks are utilized to cool CPUs, GPUs, and some chipsets and RAM modules. Heat Sinks are utilized with high power semiconductor gadgets, where the heat scattering capacity of the segment itself is inadequate to direct its temperature.

Fig.: Heat Sink With Fan (Hot Side)

Fig.: Heat Sink With Fan (Cold Side)

III. HEAT TRANSFER PRINCIPLE

3.1 *HEAT SINK*

A Heat Sink moves warm vitality from a higher temperature gadget to a lower temperature fluid medium. The fluid medium is every now and again air, yet can likewise be water, refrigerants or oil. In the event that the fluid medium is water, the heat sink is every now and again called virus plate. In Thermodynamics a heat sink is a heat supply that can ingest subjective measure of heat without fundamentally evolving temperature. To comprehend the rule of a heat sink, think about Fourier's law of Conduction. Fourier's law of heat conduction, improved to a one-dimensional structure in the X-heading, demonstrates that when there is a temperature inclination in a body, heat will be moved from the higher temperature locale to the lower temperature district [11]. The rate at which heat is moved by conduction, qk, is relative to the result of the temperature slope and the cross-sectional zone through which heat is moved.

$$qk = -kA \quad \textbf{(1)}$$

Considering a heat sink over a duct. Accepting a heat sink base temperature is higher than air. Presently applying preservation of vitality condition for steady-state conditions, and Newton's law of cooling to the given conditions

$$Q = \dot{m}c_{p,in}(T_{air,out}-T_{air,in}) \quad \textbf{(2)}$$

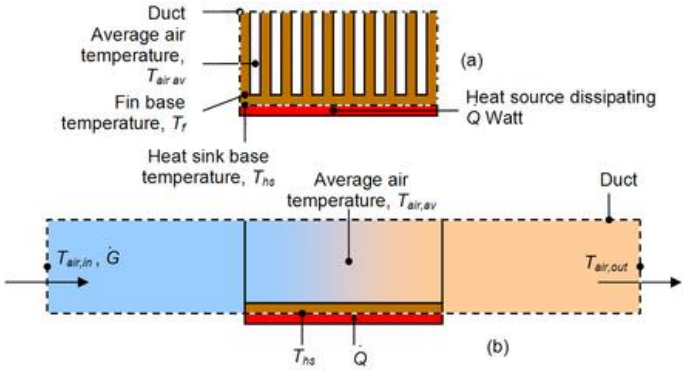

Figure 5 Heat Sink Assembly

The above equations show that –

- When the wind stream through the heat sink diminishes, this outcome in an expansion in the normal air temperature. This thus builds the heat sink base temperature. Furthermore, moreover, the thermal resistance of the heat sink will likewise increment. The net outcome is a higher heat sink base temperature.
- The channel air temperature relates emphatically with the heat sink base temperature. For instance, if there is recirculation of air in an item, the channel air temperature isn't the encompassing air temperature. The delta air temperature of the heat sink is hence higher, which likewise results in a higher heat sink base temperature.
- If there is no wind stream around the heat sink, vitality can't be moved.
- A heat sink isn't a gadget with the "mysterious capacity to assimilate heat like a wipe and send it off to a parallel universe"

3.2 THERMAL GREASE

Thermal Grease (additionally called CPU grease, heat glue, heat sink compound, heat sink glue, thermal compound, thermal gel, thermal interface material, or thermal glue) is a thermally conductive (yet typically electrically protecting) compound, which is normally utilized as an interface between warmth sinks and warmth sources, for example, high-control semiconductor gadgets [12]. The principle job of thermal grease is to dispose of air holes or spaces (which go about as thermal insulation) from the interface territory so as to augment warmth move and scattering. Thermal grease is a case of thermal interface material.

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Figure 6 Thermal Grease

Table 3 Specification of Thermal Grease

Items	HY710	Unit
Colour	Silver	2G
Thermal Conductivity	3.17	W/m-K
Thermal Impedance	0.067	°C-inches^2/Watt
Specific Gravity	2.4	gm/cm^3
Viscosity	-	-
Thixotropic Index	380 10	1/10mm
Moment Bore Temperature	50-280	ºC
Operation Temperature	30-240	°C

3.3 PARAMETERS OF A THERMOELECTRIC MODULE

When it is chosen that thermoelectric cooler is to be considered for a cooling framework, the following stage is to choose the thermoelectric module or cooler that can fulfill a specific arrangement of prerequisites. Modules are accessible in incredible assortment of sizes, shapes, working flows, working voltages and scopes of warmth siphoning limit. The base particulars for finding a fitting TEC depend on the accompanying parameters. The cutaway of a TEC has appeared in Fig 11

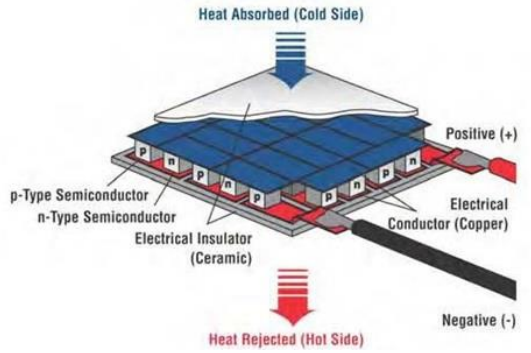

Figure 7 Cross-sectional view of Peltier element

a. Cold side temperature. (Tc)
b. Hot side temperature. (Th)
c. Operating temperature difference, which is the temperature difference among Th and Tc.
d. Amount of warmth to be assimilated at the TEC's cold surface. This can likewise be named as warmth load. It is spoken to as (Qc) and the unit is Watt.
e. Operating current (I) and operating voltage (V).

3.3.1 Cold Side Temperature

In the event that the item to be cooled is in direct contact with the virus surface of the TEC, the required temperature can be viewed as the temperature of the virus side of TEC (Tc). Here in this venture the article is air inside the volume, which must be cooled when gone through Aluminium warmth sink. The point is to cool the air moving through the warmth sinks. At the point when this sort of framework is utilized the virus side temperature of the TEC is should have been a few time colder than a definitively wanted temperature of the air.

3.3.2 Hot Side Temperature

The hot side temperature (Th) is primarily founded on the two components. The first parameter is the temperature of the encompassing air in condition to which the warmth is been rejected. The second factor is the productivity of the warmth sink that is between the hot side of TEC and the surrounding

3.3.3 Temperature Difference

The two temperatures Tc and Th and the contrast between them ΔT is a significant factor. ΔT must be precisely decided whether the cooling framework is relied upon to work as wanted. The accompanying condition demonstrates the real ΔT.

$$\Delta T = T_h - T_c$$

Genuine ΔT isn't the same as the framework ΔT. Real ΔT is the difference between the hot and cold side of the TEC. Then again framework ΔT is the temperature difference between the ambient temperature and temperature of the heap to be cooled.

3.3.4 Cooling Load

The most troublesome and significant factor to be precisely determined for a TEC is the measure of warmth to be evacuated or assimilated (Qc) by the virus side of the TEC. In this task, Qc was determined by finding the result of the mass stream rate of air, explicit warmth of air and temperature difference. Here the temperature difference framework ΔT in the difference between the delta temperature and outlet temperature of the cooling framework. The scientific condition for Qc is as demonstrated as follows.

$$Q_c = m * c_p * \Delta T$$

3.3.5 Power Supply and Temperature Control

Power supply and temperature control are two included things that must be viewed as admirably for a fruitful TE framework. TEC is an immediate current gadget. The nature of the DC current is significant. Current and voltage of a TEC can be controlled by the diagrams given by the maker. TEC's power is the result of the required voltage and current. (P = VI).

3.3.2 Thermoelectric Air Cooling for 0.08m^3 PUF Box

This manufactured exploratory arrangement has been produced for study and investigation reason.

The arrangement has been effectively rune for 10 continuous days at an interim of 6 hours beginning from midnight 12:00 AM then morning 6:00 AM, evening 12:00 and at night 6:00 PM.

Readings for these 10 days working has been cumulated and will be given in Result part.

3.3.6 Design

The thermoelectric cooling fan configuration was performed dependent on certain mechanical and electrical counts. The model gathering begins with a fundamental fan which is utilized to blow the surrounding air through a roundabout opening. The round opening is joined to a fan and leads toward warmth sink. The air which is gone through the

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round gap goes onto the warmth sink. This warmth sink goes about as a channel for the air to go through. TEC cold side or the base side lays on the virus sink. The hot side or the top sides of the TEC is secured together with the warmth sink. The TEC is introduced between the warmth sink and cold sink utilizing warm oil, which builds the warm conductivity by adjusting sporadic surface of the warmth sink. At the point when the TEC is inactivity cold side of the TEC chills off the virus sink channel. Air which is turning out from the channel is chilled air which is lower than the encompassing temperature. The virus side warmth sinks lay on a PUF base. The entire gathering is encased with aluminium foil.

Figure 8 Picture of a complete setup

3.4 COMPUTATION OF COOLING POWER

The measure of warmth evacuated or the cooling force was resolved before the choice of the TEC. Qc which is the measure of warmth consumed was determined utilizing the condition. Mass stream rate (m) of air is the result of thickness of air (ρ) and volume stream rate (Q). Thickness of air at 30 °C was taken as1.164 kg/m3. Q was acquired by duplicating speed of air going through the round opening of warmth sinks and the cross-segment zone of a warmth sink. It is signified by the condition (Q =V × A). Speed of the air going through the round opening was estimated utilizing an anemometer and brought about a perusing of 3m/s. Cross-sectional region of round opening (A=πr^2) was determined as 0.001256m2 with span of 0.02m and the volume stream rate was 0.003768m3/s Specific warmth of air (C) at 30 °C was taken as1007 J/kg K. The framework ΔT is the distinction between the surrounding temperature and the temperature of the heap to be cooled. It had been focused to accomplish a temp of 20°C structure the surrounding temperature (32 °C). As it were the info temperature from the roundabout gap is 32 °C and the normal yield is 20°C.

$$\Delta T = T_{in} - T_{out} = 32°C - 20°C = 12°C$$

$$Q_c = m * c_p * \Delta T$$

$$m = \rho * Q$$

$$Q = A * V$$

Where ρ Density

Q Volume flow rate

A Cross-Sectional Area of Circular Hole

V Speed of Air through a circular hole(3m/s).

The amount of heat load for cooling the air through the rectangular duct was calculated as 55W.

3.5 CALCULATIONS

All counts utilized in the venture, identified with cooling load, choice of heat sinks, determination of fans, weight drop figurings, surface region expected to cool the air and so on are referenced beneath

Cooling load(Qc)

Qc the summed heat load to be consumed by the cold junction must be determined before the determination of TEC

$$Q_c = m * c_p * \Delta T$$

$$m = \rho * Q$$

$$\rho = 1.164 kg/m^3 \text{ (At 30°C)}$$

$$Q = A * V$$

$$A = \pi r^2$$

$$COP = 0.458$$

This was not the actual COP of the system. It can be higher, as the power input designed is higher than the calculated Q_c. Higher power input for TECs was selected in the project. The system was designed with higher power input. Therefore the actual COP can even higher.

3.5.1 Thermal Resistance of the Hot side Heat Sink

A hot side heat sink must be chosen dependent on its Thermal obstruction. The warm opposition of the hot side heat sink is determined beneath.

$$R_t = 0.0272 K/W$$

3.5.2 Power of Fan

Table 4 Specification of Cooling Fan

Property	Value
Rated Voltage	12VDC
Operational Voltage	8-13.5VDC
Input Current	0.09Ampere
Input Power	1.08Watt
RPM	3000 10%
Maximum Airflow At Zero Static Pressure	0.43m^3/min
Maximum Air Pressure At Zero Flow	2.31mm-H_2O 0.09inch-H_2O

The power of the fan will be equivalent to the product of all-out pressure drop (pt) and volume stream rate. The all-out pressure drop will be the whole of pressure drop in cold side heat sink channel (rectangular channel) and the circular hole which will be considered as short circular duct.

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3.5.3 Surface Area needed to Cool the Air

Surface area required to cool the air. The calculations are computed below.

$$Q_c = m * c_p * \Delta T$$

$$Q_c = h * A * \Delta T$$

$$A = Q_c / h\Delta T$$

Different sets of Reading have been taken for 10 Consecutive days at an equal time interval of 6 hours daily. The results for different time are plotted in the following chapter.

Time of reading

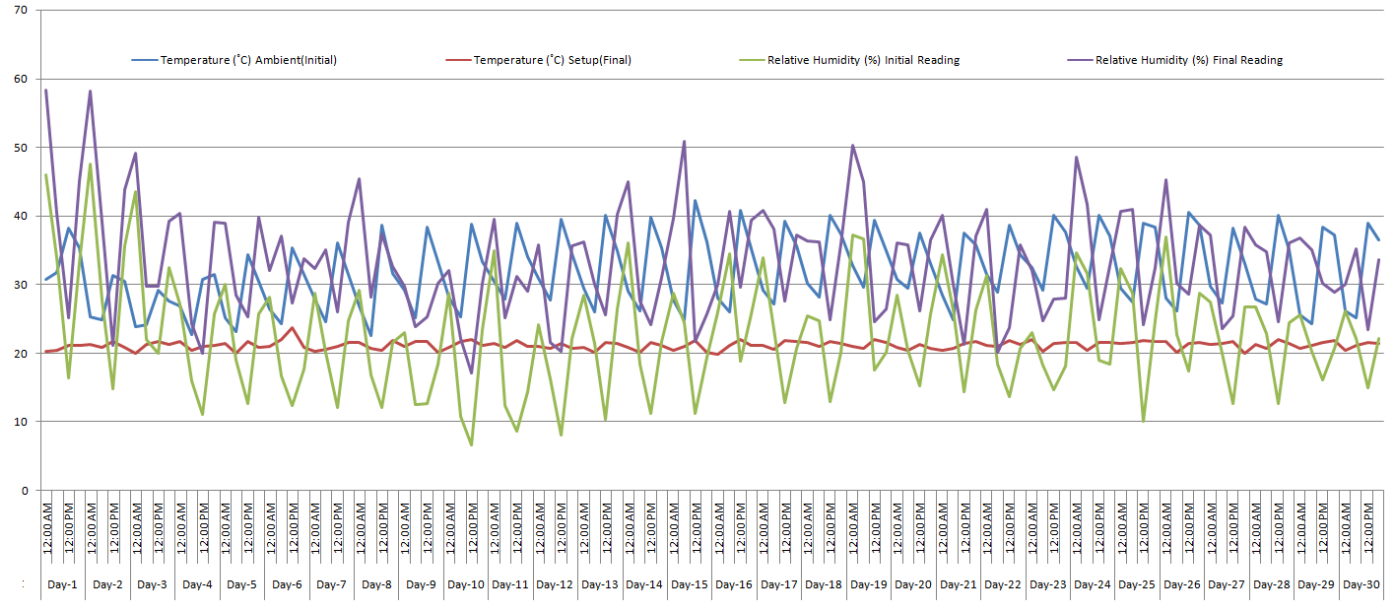
The experiments were performed for 10 consecutive days at an interval of 6 hours beginning from 12:00Mid Night, Morning 6:00 AM, 12:00Noon and Evening 6:00 PM. This full-day by day readings is taken for 10 days to peer hourly variations in temperature drop for one of a kind times when the variation might be most.

IV. RESULTS

The experimental installation runs for 1 hour every 6 hours. Time c language between successive readings changed into kept 1 minute. Parameters that are recorded in reading areas-

- Time
- Temperature(°C)
- Light Intensity (Lux)
- Relative Humidity

Cumulative readings of 4 times a day for 30 days are shown below.



Graphical representation for an hourly variation after every 6 hours is shown below.

The model can be made smaller by choosing increasingly efficient TEC of a higher power (.for example of 200W or more). It can be done by selecting a superior cold side heat sink that has bent channels or pipes for circling the air for a more extended time. As an option for typical pivotal fan utilized in this venture, if a blower fan is chosen, the cooling framework would give better airflow. A large hot side heat sink must be chosen precisely dependent on its determined heat protections for best cooling efficiency. With an increasingly productive TEC, one hot side and a cool side heat sink, TEC cooler give more comfort which can be created and can be introduced on rooftop for individual cooling by changing the wind stream and some mechanical or hardware section modifications, the TEC air cooling for home can be utilized for cooling applications.

Following results had been concluded from the experiment-

- Selection of TEC12706 for air space cooling was found correct as the cooling load had been taken care of by the Peltier element.
- Cooling load in the volume of 0.08m^3 was found to be 55Watts.
- COP (Coefficient of Performance) of the system was found to be 0.458.
- Thermal Resistance of the hot side heat sink was found to be 0.0272K/W.
- Pressure drop in the volume after cooling was found to be 0.0982N/m^2.
- Surface area needed to cool the air was found to be 0.0916m^2.

V. CONCLUSION

A Thermoelectric Air cooling framework was planned and constructed which can be utilized for individual cooling. Results were utilized for accomplishing the cooling with a DC power supply through SMPS. It had appeared from testing results that the cooling framework is fit for cooling the air when worked for 60 minutes, moreover required temperature had been achieved simply following 60 minutes of operation.TEC cooling design had the capacity to cool an

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encompassing air temperature from32°C to 20°C. Cooling balances out, inside ten minutes once the blower is turned ON (with a speed of 3 m/s). The framework can accomplish a temperature contrast of set target which was 20°C. Achieving the set target set up the achievement of the undertaking. Each part in the venture had been tried separately and the outcomes were observed to be certain. Hence, it can be used in small domestic application.

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