International Journal of Thermal Technologies

E-ISSN 2277 – 4114
Available at http://inpressco.com/category/ijtt/

Research Article

Cooling Arrangement for Traffic Police Booth

K. Augustine Babu†* and P. Sherjin†

†Department of Mechanical Engineering, Sri Ramakrishna Institute of Technology, Coimbatore, Tamil Nadu, India

Accepted 10 Sept 2016, Available online 23 Sept 2016, **Vol.6, No.3 (Sept 2016)**

Abstract

The inside temperature of a traffic police booth is found to be at a higher level during sunny days, which causes discomfort to the person standing within it. Reducing this high inside temperature of the booth is the ultimate aim of this work. Use of semi-conductor based thermoelectric modules can greatly influence in altering the temperature of the unit in relation with the ambient condition. In this design, water is stored in a reservoir placed beneath the booth and is circulated through the sides of the booth, from the bottom up to the roof by means of pipes. Thermocouples are fixed at different regions and the set up was tested at different conditions. The results showed a subsequent drop in temperature with this arrangement provided when compared with those obtained without the set up. Thus the design proves to be a promising door for controlling the temperatures inside the booth and may provide a gateway for any advancement in future.

Keywords: *Cooling Arrangement, Traffic Police Booth, Thermoelectric Modules, Peltier Effect, Thermal Analysis.*

1. Introduction

The performance of human being is greatly affected by his surroundings. This is also true in the case of the policeman, who stands under the traffic police booth. The temperature under the roof of the booth is found to be higher than the comfort level of an individual, especially, when the sun is hot at the peak. Reducing the inside temperature range for traffic police booth could increase the effectiveness of the person and improve his work. This objective can be attained by using thermoelectric module and heat exchanger. Experimental investigation shows that the increase in the temperature of the earth by almost 10% is contributed by HFC's only, which are commonly used in air conditioners (Prof. N. B. Totala, Prof. V. P. Desai and Rahul K. N. Singh, 2014). This has led to the use of an alternative system of conventional cooling, i.e. thermoelectric cooling and heating. The TE module is a semiconductor based electronic component working on the principle of Peltier effect. Thermoelectric devices (thermoelectric modules) can convert electrical energy into a temperature gradient. The thermoelectric materials enable direct conversion between thermal and electrical energy by thermoelectric effect and hence they provide an alternative for refrigeration and power generation (Xiao Zhang and Li-Dong Zhao, 2015). The application of this cooling or heating effect remained minimal until the development of semiconductor materials. With the advent of semiconductor materials come the capabilities for a wide variety of practical thermoelectric refrigeration applications.

Thermoelectric refrigeration is achieved when a direct current is passed through one or more pairs of n and p-type semiconductor materials. In the cooling mode, direct current passes from the n to p-type semiconductor material. The temperature of the interconnecting conductor decreases and heat is absorbed from the environment. This heat absorption from the environment (cooling) occurs when electrons pass from a low energy level in the p-type material through the interconnecting conductor to a higher energy level in the n-type material.

The absorbed heat is transferred through the semiconductor materials by electron transport to the other end of the junction and is liberated as the electrons return to a lower energy level in the p-type material. This phenomenon is called the Peltier effect. Just by applying a low DC voltage to this module, one surface gets cold and the other surface gets hot. And just by reversing the applied DC voltage, the heat moves to the other direction. Thus, this thermoelectric device works as a heater or a cooler. Higher the differential temperature, higher the electric power and electromotive force. When the electrical connections between two modules were serial, the power generated was more (N. Sangwaranatee and N. W. Sangwaranatee, 2015). In order to verify the Peltier effect heat pump, a refrigeration system was designed and fabricated by using Peltier modules. Then it was tested experimentally and stimulated with Spice. The results from that of simulation and experimentation were found to be compatible. The model ensures better design of thermal systems using Peltier modules

*Corresponding author: **K. Augustine Babu**

(Chakib Alaoui, 2011). Water cooling is a method of heat removal from components and industrial equipment. As opposed to air cooling, water is used as the heat conductor. Free cooling can be provided by circulating water between ground heat exchanger (GHE) and the indoor directly (Yi Man and Hongxing Yang, 2015). The main mechanism for water cooling is transfer or circulation. In this project water was stored in reservoir and pumped to roof after return to reservoir. Evaporative cooling is a high temperature cooling solution that can save energy compared to refrigerant cooling systems and also, provide more cooling reliability than mechanical or natural ventilation system without cooling (Michal Pomianowski, Christian Hede Andersen and Per Heiselberg, 2015). An evaporative cooler produces effective cooling by combining natural process- water evaporation with a simple, reliable air moving system. Evaporative cooling is the most economical and effective means of refrigeration and air cooling since its inception particularly in the areas where climatic conditions are warm and dry (Poonia M.P., Bhardwaj A., Upender Pandel and Jethoo A.S.,2011).

Copper and copper alloys offer a unique combination of material properties that makes them advantageous for many manufacturing environments. They are widely used because of their excellent electrical and thermal conductivities, outstanding corrosion resistance, ease of fabrication, and good strength and fatigue resistance. Copper does not react with water but it does slowly react with atmospheric oxygen to form a layer of brown-black copper oxide which, unlike the rust which forms when iron is exposed to moist air, protects the underlying copper from more extensive corrosion. Alternatively, structural steel can also be used. In our project we use thermoelectric module as a power supply device. The low thermal conductivity wax based phase change material has limited its application in latent heat thermal energy storage system (TES). Two ways are there to increase the thermal conductivity of wax by a factor of more than 100. The first involves embedding a modified copper tube / aluminium fin heat exchanges of the type typically used in room air conditioner in a container filled with wax based phase change material.

The second one is a more unconventional approach, to embed copper tube circuits into high conductivity graphite –wax composite (Yoram L. Shabtai, John R.H. Black2014). High performance thermoelectric materials can directly convert heat to electrical energy. When activated during the summer months, the system will operate in one of the four cooing modes. 1) Free outside air cooling 2) Direct evaporative cooling 3) Direct and indirect cooling 4) Direct and indirect cooling and dehumidification. The dehumidifier is used in conjunction with the indirect and direct evaporative cooling as this increase the system's ability to cool the air, by reducing both the dry and wet bulb supply air temperatures. In order to determine the interior air temperature and the corresponding heating or cooling loads required to maintain a constant inside temperature the following assumptions are made 1)the air is uniformly mixed inside so that uniformly distributed temperature T1 is considered 2)clear sky solar radiation model is applied 3)steady stage energy exchange process is assumed. Experimental study on the cross flow air cooled plate heat exchanger using fin with electric pump was performed. Two prototype plate heat exchangers were manufactured in a stack of single wave plate and double wave plate in parallel. Cooling air flows through the plate heat exchanger in a cross-wise direction against interface cooling water (Pankaj Kumar Mishra, 2015). Based on these literature reviews, effective arrangements necessary for cooling of the booth of the traffic policeman is designed. A model of the booth was fabricated and was tested by circulating water, thermoelectric modules and providing additional cooling arrangements by traditional methods of using banana leaves and river sand. Also, an analysis of the arrangement was done. The results obtained are explained in this paper.

2. Experimentation

In order to determine the interior air temperature and the corresponding heating or cooling loads required to maintain a constant inside temperature the following assumptions are made 1)the air is uniformly mixed inside so that uniformly distributed temperature T1 is considered 2)clear sky solar radiation model is applied 3)steady stage energy exchange process is assumed. As a result, the energy balance equation for inside air is

$$E_{ab} + E_{crop} + E_v + E_L + E_{req} = 0 \quad (1)$$

When heating is required, E_{req} will be positive. In case of cooling necessity E_{req} will be negative.

2.1 Experimental setup

The experimental arrangement of the set up and the various components, with their systematic arrangement is shown in the figure 1.

The major components of the arrangement are a reservoir to store water, a pump, thermoelectric modules, DC battery, thermocouples and the test booth. The experimental set up was done with the help of a test booth section made of copper. The four legs of the booth were made up of rods of square cross section and one meter long. The legs were made hollow to reduce the weight, yet provide the necessary stiffness. The outer body was made with a hollow circular cross section and it rests over a platform on the legs. A small gap was provided at one end, in order that the person may get into the chamber. The section was made with an inner radius of 0.24m and with an outer radius of 0.3m. The covers at the upper end of the booth was made of circular cross section and has dimensions of 0.3m at the outer end and 0.29m at the inner end. At the top of the section a cone shape cover was provided for necessary shade. It has dimensions of 6m at the wider end and has a height of 4m with an enclosing angle of 57 degree. The reservoir was provided at the bottom of the arrangement and it was filled with water for circulation around the tank. A pump was connected to the reservoir for increasing the pressure of the stored water. Thermo electric modules were placed at fixed positions inside the copper booth. Copper was used as a material for the booth as it possesses good thermal and electrical properties and also, it has high resistance to corrosion. The DC power supply from a battery was supplied to the thermoelectric modules. Thermocouples were provided in order to measure the temperature at different time intervals. The water from the reservoir was circulated around the test booth using tubes passing between the hollow copper enclosures. The tubes were surrounded with proper insulating material to avoid any heat transfer through the medium. Thermocol was used to prevent the atmospheric heat from entering the room.

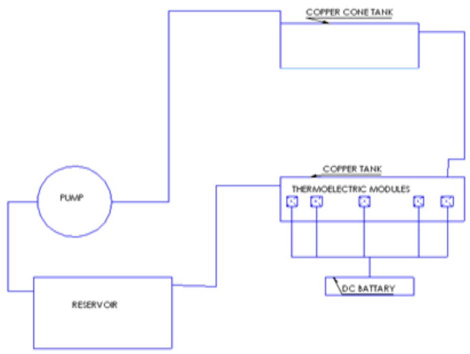

Fig.1 Proposed layout of the experimental setup

2.2 Description of the Components

The major components used in the experimental arrangement, their description, operation and functions are explained in this section.

2.2.1 Centrifugal Pump

Centrifugal pumps are the most commonly used kinetic-energy pump. Centrifugal force pushes the liquid outward from the eye of the impeller where it enters the casing. Differential head can be increased by turning the impeller faster, using a larger impeller, or by increasing the number of impellers. The impeller and the fluid being pumped are isolated from the outside by packing or mechanical seals. Shaft radial and thrust bearings restrict the movement of the shaft and reduce the friction of rotation.

Pump specific speed

Pump specific speed is the speed in revolutions per minute required to produce a flow of 1 gal/min with a TDH of 1 ft, with an impeller similar to the one under consideration but reduced in size. The pump specific speed links the three main components of centrifugal-pump performance characteristics into a single term. It is used to compare two centrifugal pumps that are geometrically similar. Pump specific speed can be calculated from

$$N_s = \frac{N\sqrt{q}}{(H_{td}')^{0.75}} \qquad (2)$$

where,

N_s = pump specific speed

N = pump rotative speed

q = pump capacity

H_{td}' = TDH per stage at the BEP.

The pump specific speed is always calculated at the pump's point of maximum efficiency. The number is used to characterize a pump's performance as a function of its flowing parameters. Normally, it is desirable to select the impeller with the highest specific speed (smallest diameter). This may be offset by the higher operating cost associated with higher speeds and greater susceptibility to cavitation damage.

2.2.2 Temperature Indicator

A temperature sensor is a device, typically, a thermocouple that provides for temperature measurement through an electrical signal. A thermocouple (T/C) is made from two dissimilar metals that generate electrical voltage in direct proportion to changes in temperature.

Thermocouple

A thermocouple is made from two dissimilar metal wires. The wires are joined together at one end to form a measuring (hot) junction. The other end, known as the reference (cold) junction, is connected across an electronic measurement device (controller or digital indicator). A thermocouple will generate a measurement signal not in response to actual temperature, but in response to a difference in temperature between the measuring and reference junctions. A small ambient temperature sensor is built into the electronic measuring device near the point where the reference junction is attached. The ambient temperature is then added to the thermocouple differential temperature by the measuring device in order to determine and display the actual measured temperature. Only two wires are necessary to connect a thermocouple to an electrical circuit; however, these connecting wires must be made from the same metals as the thermocouple itself. Adding wire made from other materials (such as common copper wire) will create new measuring junctions that will result in incorrect readings.

2.2.3 Thermoelectric Module

Thermoelectric coolers are solid-state heat pumps that operate according to the Peltier effect: a theory that claims a heating or cooling effect occurs when electric current passes through two conductors. A voltage applied to the free ends of two dissimilar materials creates a temperature difference. With this temperature difference, Peltier cooling will cause heat to move from one end to the other.

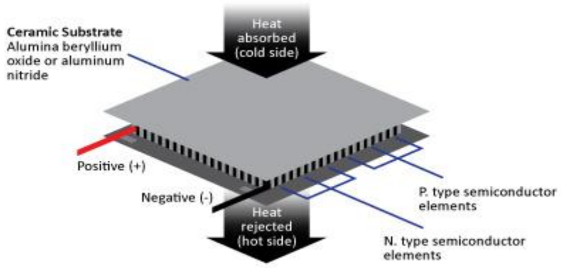

Fig.2 A typical thermo electric cooler

A typical thermoelectric cooler will consist of an array of p and n type semiconductor elements that act as the two dissimilar conductors. The array of elements is soldered between two ceramic plates, electrically in series and thermally in parallel. As a DC current passes through one or more pairs of elements from n- to p-, there is a decrease in temperature at the junction ("cold side"), resulting in the absorption of heat from the environment. The heat is carried through the cooler by electron transport and released on the opposite ("hot") side as the electrons move from a high- to low-energy state.

The heat-pumping capacity of a cooler is proportional to the current and the number of pairs of n- and p- type elements (or couples).

N- and p-type semiconductors (usually Bismuth Telluride) are the preferred materials used to achieve the Peltier effect because they can be easily optimized for pumping heat. They can also control the type of charge carrier within the conductor.

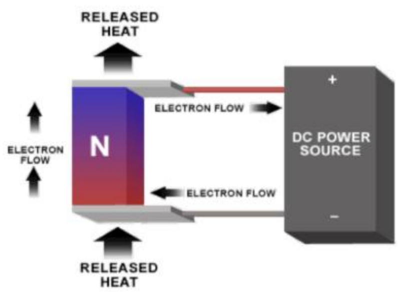

Fig.3 N-type Semi-Conductor

Figure 3 illustrates an "N-type" semiconductor element utilized to facilitate the Peltier effect. In this example, negatively charged electrons are repelled by the negative pole and attracted to the positive pole of the DC power source. This forces electron flow in a clockwise direction through the "N-type" material. Heat is absorbed at the bottom junction and actively transferred to the top junction by the electrons as they flow through the semiconductor element. This is known as electron transport.

Performance

A single-stage TEC will typically produce a maximum temperature difference of 70 °C between its hot and cold sides. The more heat moved using a TEC, the less efficient it becomes, because the TEC needs to dissipate both the heat being moved, as well as the heat it generates itself from its own power consumption. The amount of heat that can be absorbed is proportional to the current and time.

$$Q = PIt \tag{3}$$

where, P is the Peltier Coefficient, I is the current, and t is the time. The Peltier Coefficient is dependent on temperature and the materials the TEC is made of.

Peltier (thermoelectric) cooler performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, Peltier module (thermopile) geometry, and Peltier electrical parameters. Thermoelectric junctions are about 4 times less efficient in refrigeration applications than conventional means (they offer around 10–15% efficiency of the ideal Carnot cycle refrigerator, compared with 40–60% achieved by conventional compression cycle systems (reverse Rankine systems using compression/expansion)) Due to this lower efficiency, thermoelectric cooling is generally only used in environments where the solid state nature (no moving parts, low maintenance, compact size, and orientation insensitivity) outweighs pure efficiency.

Requirements for thermoelectric materials

- Narrow band-gap semiconductors because of room temperature operation
- Heavy elements because of their high mobility and low thermal conductivity
- Large unit cell, complex structure
- Highly anisotropic or highly symmetric
- Complex compositions

Common thermoelectric materials used as semi-conductors include bismuth telluride, lead telluride, silicon germanium, and bismuth-antimony alloys. Of these bismuth telluride is the most commonly used. New high-performance materials for thermoelectric cooling are being actively researched.

Some benefits of using a TEC are

- No moving parts so maintenance is required less frequently

- No chlorofluorocarbons (CFC)
- Temperature control to within fractions of a degree can be maintained
- Flexible shape (form factor); in particular, they can have a very small size
- Can be used in environments that are smaller or more severe than conventional refrigeration
- Long life, with mean time between failures (MTBF) exceeding 100,000 hours
- Controllable via changing the input voltage/current

3. Methodology

The apparatus consists of a reservoir, centrifugal pump, a copper cone tank, a copper tank and a thermo electric module working on a DC battery. First water is stored in the reservoir which is already filled with river sand and banana fibres. This cold water from the reservoir is pumped using a centrifugal pump to the copper cone tank at the top. The water is continuous pumped to the cone tank. The water overflowing from the copper tank flows to the copper tank at the base. The copper plate around the tank gets cold and thus by decreasing the temperature inside the shell. Extra cooling is provided by the thermoelectric module which is attached to the copper tank. This thermoelectric module works by a DC battery. Now the water which over flows from the copper tank goes back to the reservoir and the cycle goes on. For more insulation, a layer of thermo coal is present in between the sheet metal outer layer and the copper tank.

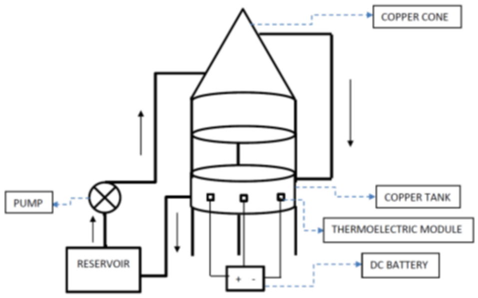

Fig.4 Water Circulation

3.1 Water Circulation

The circulation of water around the apparatus is shown in the Figure 3.1. Initially the water from the reservoir is pumped to copper cone tank through centrifugal pump. The open valve is fitted at the top of the copper cone tank. The water overflows through the valve and is sent to the lower portion of the copper tank. This copper tank also consists of open valve at the bottom. So the water overflow through this valve and sent to the reservoir. Then the cycle is continued again and again.

3.2 Heat Absorption from Water

The reservoir consists of river sand and banana leaves. The river sand gives cooling effect to water. The banana leaves also gives cooling effect to the water .The banana leaves can cool the water continuously for twelve days.

3.3 Thermoelectric Cooling

Thermoelectric Cooling is provided in the apparatus by means of using thermoelectric modules. DC current is passed through one or more pairs of elements from n-side to p-side, and hence there is a decrease in temperature at the junction ("cold side"), resulting in the absorption of heat from the environment. If the flow is from p-side to n-side, there is an increase in temperature at the junction (“hot side”), resulting in releasing the heat. This heat is transferred by the copper tank which contains the water for circulation.

3.4 Thermoelectric Module

The selection of thermoelectric module or thermoelectric cooler (TEC) plays a major role. The selection of TEC is based on certain parameters and calculation as it is involved in conventional system. These calculations depend on the power supplied and area to be cooled.

The important parameters to select the TEM are, ΔT_{max} , I_{max}, V_{max} and Q_{max}.

$$\Delta T_{max} = \frac{1}{2} Z T_c{}^2 \tag{4}$$

$$I_{max} = \frac{S_M}{R_M}[T_h - \Delta T_{max}] \tag{5}$$

$$V_{max} = S_M \Delta T_{max} + I_{max} R_M \tag{6}$$

$$Q_{max} = S_M T_c I_{max} - \frac{1}{2} I^2{}_{max} R_M \tag{7}$$

Thus, the required basic parameters are calculated, according to which the thermoelectric modules are selected.

Table 1 Thermoelectric Module Specifications

TYPE: TEC-12706		
Resistance	2.05Ω±10˚C	
I_{max}	6.0A	
V_{max}	15.4V	
	T_h=27˚c	T_h=50˚C
Q_{max}	53.0W	59.5W
ΔT_{max}	68˚C	75˚C
Solder melting point	138˚C	
Compression strength	1Mpa	

4. Results and Discussions

The experimental arrangement was done as described and it was tested in different conditions of cooling. The temperature drop was observed first by circulating water only, and then by circulating water in addition to using thermoelectric coolers and finally by using thermoelectric coolers, river sand, banana leaves in addition to circulating water.

The graph is plotted for Temperature Vs Time for the different conditions of cooling of the booth.

4.1 Water Circulation Only

The graph in figure 5 shows the temperature variations for different time across the day, by circulating water through the pipes in between the copper enclosure. From the graph it is clear, the temperature inside the booth increases steadily from morning and reaches a peak value by the afternoon and then decreases steadily during the evening time. The maximum temperature reached is approximately 34 degree Celsius and the temperature throughout the day lies above 30 degrees.

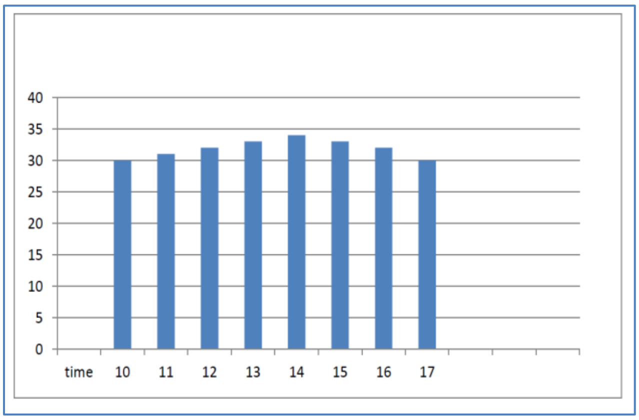

Fig.5 Water Circulation only

4.2 Water Circulation and Thermoelectric Cooling

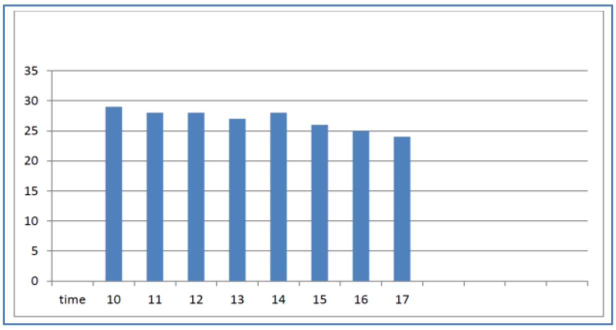

Fig.6 Water Circulation and thermoelectric cooling

The graph in figure 6 gives the temperature variation inside the booth for different time of the day. It can be inferred that there is a drop in temperature inside the booth when thermoelectric cooler is used in addition to circulating water when compared with the cooling obtained when water alone is circulated surrounding the chamber. The temperature limits throughout the day are maintained below 30 degree Celsius and it reaches the lowest value of 24 degrees during the evening. Also, it is clear from the results that the temperature inside the booth almost remains a constant value and there is no sudden increase in temperature between the morning and afternoon durations of the day. During the afternoon there is almost 10 degree Celsius drop in temperature by the use of thermoelectric coolers. As a result of this drop in temperature and as the temperature limits inside the booth are within the comfort level of the person inside the booth, the efficiency of the person is increased.

4.3 Water Circulation and Thermoelectric Cooling with the usage of River Sand and Banana Leaves

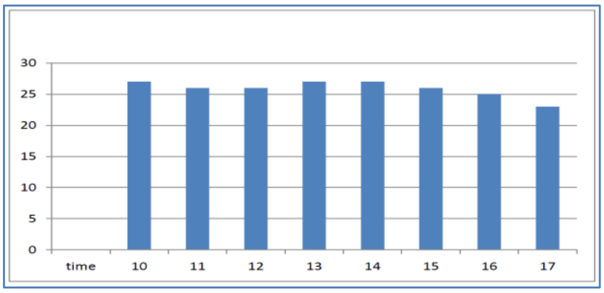

Fig.7 Water Circulation with thermoelectric cooling and the use of river sand and banana leaves

For further drop in temperature of the booth, natural, cheap and easily available materials with cooling effect like river sand and banana leaves are used in addition to water circulation and thermoelectric cooler. As a result of this, the temperature of the booth at the inside is further reduced by few degrees. By this method, the result obtained indicates that the temperature inside the booth remains under 28 degree Celsius throughout the day as indicted by figure 7.

4.4 Analysis

The analysis of the experimental set up was also done. The results obtained are given as follows.

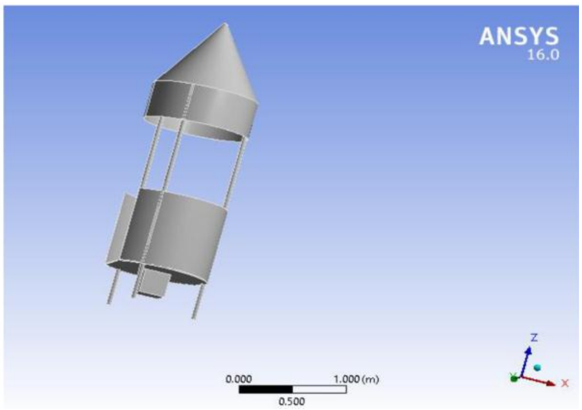

Fig.8 Analysis Component

4.4.1 Geometry

Table 2 Geometry

Object Name	Solid
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behaviour	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Copper
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	1m
Length Y	1m
Length Z	3.18m
Properties	
Volume	0.24826 m^3
Mass	1948.8 kg
Centroid X	2.1004e-003 m
Centroid Y	-1.6864e-004 m
Centroid Z	1.9104 m
Moment of Inertia I_p1	1184.6 kg m^2
Moment of Inertia I_p2	1182.9 kg m^2
Moment of Inertia I_p3	159.76 kg m^2
Statistics	
Nodes	42628
Elements	21348
Mesh Metric	None

4.4.2 Mesh

Table 3 Mesh

Object Name	Mesh
State	Solved
Display	
Display Style	Body Colour
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Centre	Fine
Element Size	Default
Initial Size Seed	Active assembly
Smoothing	Medium
Transition	Fast
Span Angle Centre	Course
Minimum Edge Length	3.7755e-004 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	No
Advanced	
Number of CPUs for parallel part Meshing	Program Controlled
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default(4)
Extra retries For Assembly	Yes
Rigid Body Behaviour	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	42628
Elements	21348
Mesh Metric	None

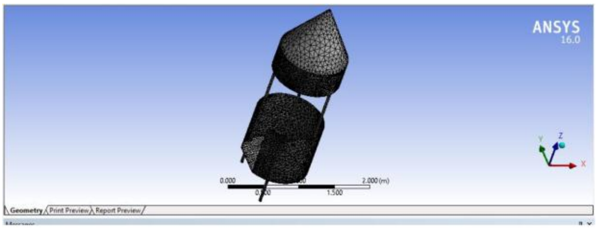

Fig.9 Mesh

4.4.3 Transient Thermal Temperature

Table 4 Transient Thermal Temperature

Initial Condition	
Object name	Initial Temperature
State	Fully Defined
Definition	
Initial Temperature	Uniform Temperature
Initial Temperature	22°C
Loads	
Object Name	Temperature
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	18 Edges
Definition	
Type	Temperature
Magnitude	95°C(step applied)
Suppressed	No

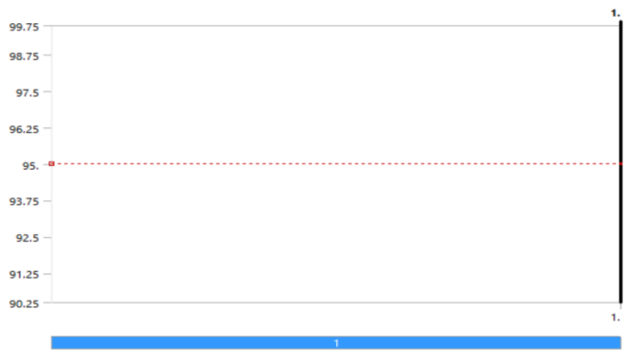

Fig.10 Transient Thermal Temperature

4.4.4 Solution

Table 5 Solution

Object Name	Solution Information
State	Solved
Solution Information	
Solution Output	Solver Output
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Colour	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

4.4.5 Result Charts

Table 6 Result Chart-1

Object Name	Temperature-Global Maximum	Temperature-Global Minimum
State	Solved	
Definition		
Type	Temperature	
Scope		
Scoping Method	Global Maximum	Global Minimum
Results		
Minimum	95^{0}C	-8.1006 ^{0}C
Maximum	122.85 ^{0}C	1.78 ^{0}C

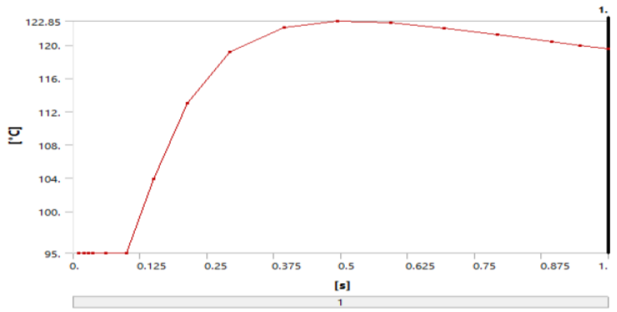

Fig.11 Temperature Global Maximum

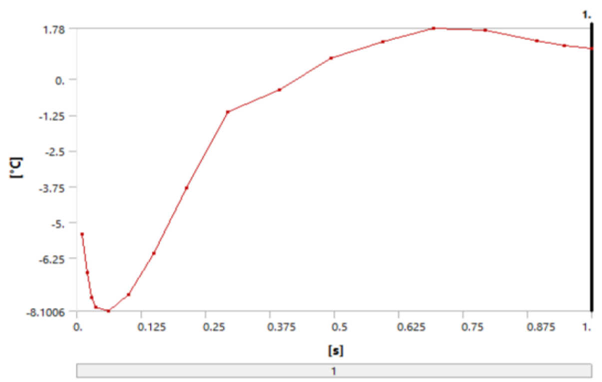

Fig.12 Temperature Global Minimum

Table 7 Result Chart-2

Object Name	Temperature	Total Heat Flux
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Temperature	Total Heat Flux
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	1.0654 ^{0}C	3.4167e-005 W/m^2
Maximum	119.49 ^{0}C	1.6744e+006 W/m^2
Minimum Value Over Time		
Minimum	-8.1006 ^{0}C	1.2552e-005 W/m^2
Maximum	1.78 ^{0}C	6.4932e-005 W/m^2
Maximum Value Over Time		
Minimum	95 ^{0}C	1.6744e+006 W/m^2
Maximum	122.85 ^{0}C	6.8567e+006 W/m^2
Information		
Time	1s	
Load Step	1	
Sub Step	17	
Iteration Number	17	
Integration Point Results		
Display Option	Averaged	
Average Across Bodies	No	

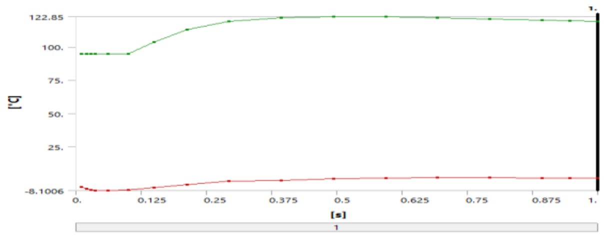

Fig.13 Time Temperature

Table 8 Temperature

Temperature		
Time[s]	Minimum[^{0}C]	Maximum[^{0}C]
1.e-002	-5.3964	95
2.e-002	-6.7395	
2.8273e-002	-7.6291	
3.6546e-002	-7.9533	
6.1366e-002	-8.1006	
9.96e-002	-7.5325	
0.1495	-6.0753	103.9
0.21248	-3.7942	113
0.29353	-1.1539	119.18

0.39353	-0.38714	122.09
0.49353	0.72789	122.85
0.59353	1.3185	122.64
0.69353	1.78	122.02
0.79353	1.7078	121.22
0.89353	1.3302	120.39
0.94677	1.177	119.94
1	1.0654	119.49

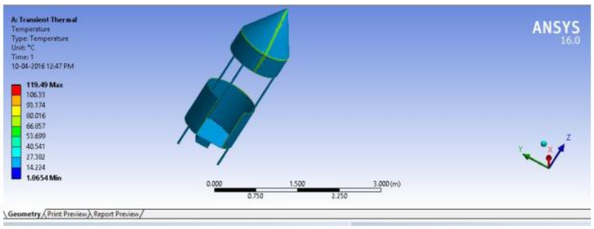

Fig.14 Transient Thermal Temperature

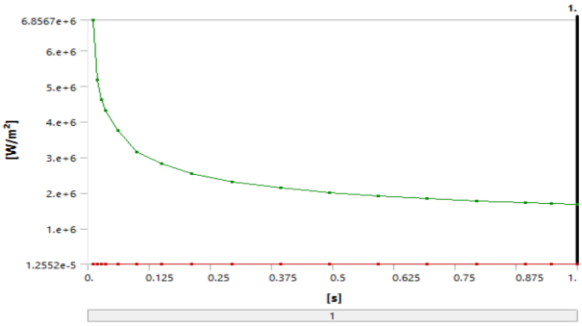

Fig.15 Total-Time Heat Flux

Table 9 Total Heat Flux

Time[s]	Minimum[W/m²]	Maximum[W/m²]
1.e-002	3.7657e-005	6.8567e+006
2.e-002	4.0773e-005	5.1706e+006
2.8273e-002	3.3159e-005	4.6279e+006
3.6546e-002	3.3228e-005	4.3262e+006
6.1366e-002	2.3741e-005	3.7648e+006
9.96e-002	1.6183e-005	3.146e+006
0.1495	1.6248e-005	2.8108e+006
0.21248	2.5319e-005	2.5348e+006
0.29353	1.2552e-005	2.3104e+006
0.39353	1.3169e-005	2.1429e+006
0.49353	3.4401e-005	2.0148e+006
0.59353	6.493e-005	1.9154e+006
0.69353	6.173e-005	1.8368e+006
0.79353	5.9722e-005	1.7736e+006
0.89353	3.9107e-005	1.7217e+006
0.94677	3.1867e-005	1.6969e+006
1.	3.4167e-005	1.6744e+006

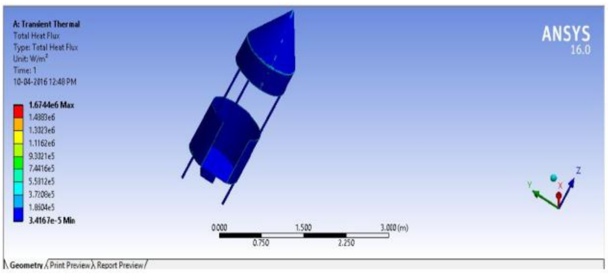

Fig.16 Total Heat Flux

4.4.6 Material Data

Copper

Table 10 Constants

Density	8950kg m^{-3}
Coefficient of Thermal Expansion	1.2e-005 C^{-1}
Specific Heat	434 J $kg^{-1}C^{-1}$
Thermal Conductivity	60.5 W m^{-1} C^{-1}
Resistivity	1.7e-007 ohm m

Table 11 Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

Table 12 Compressive Yield Strength

Compressive Yield Strength Pa
2.5e+008

Table 13 Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+008

Table 14 Tensile Ultimate Strength

Tensile Ultimate Strength Pa
4.60e+08

Table 15 Isotropic Secant Coefficient of Thermal Expansion

Reference Temperature C
22

Table 16 Alternating Stress and Mean Stress

Alternating Stress Pa	Cycles	Mean Stress Pa
4.00e+09	10	0
2.83e+09	20	0
1.90e+09	50	0
1.41e+09	100	0
1.07e+09	200	0
4.41e+08	2000	0
2.62e+08	10000	0
2.14e+08	20000	0
1.38e+08	1.00e+05	0
1.14e+08	2.00e+05	0
8.62e+07	1.00e+06	0

Table 17 Strain Life Parameters

Strength Coefficient Pa	9.20e+08
Strength Exponent	-0.106
Ductility Coefficient	0.213
Ductility Exponent	-0.47
Cycle Strength Coefficient Pa	1.00e+09
Cyclic Strain Hardening Exponent	0.2

Table 17 Isotropic Elasticity

Temperature C	
Young's Modulus Pa	2.00e+11
Poisson's Ratio	0.3
Bulk Modulus Pa	1.67e+11
Shear Modulus Pa	7.69e+10

Table 19 Isotropic Relative Permeability

Relative Permeability
10000

The main advantage of using thermoelectric modules for reducing the temperature inside the traffic booth is that it is environment friendly as it does not emit chlorofluorocarbons (CFC). Temperature control within fractions of a degree can be maintained. The thermoelectric module is of very small size and can be used in environments that are smaller and in situations in which conventional refrigeration is not sufficient. Also, the thermoelectric modules can be controlled easily by changing the input voltage or current and have long life, with mean time between failures (MTBF) exceeding 100,000 hours.

Conclusion

This experimental study is aimed at the usage of modern techniques of cooling using thermoelectric modules in order to lower the temperature inside the traffic booth, in a view of providing a more comfortable range of temperature for the police inside the booth. The peak temperature in the afternoon, when thermoelectric modules were used inside the booth with water circulation was found to be reduced by approximately 10 degree Celsius (from 36 degree Celsius to 26 degree Celsius) when compared with that of normal booth temperature without thermoelectric module. Hence, this type of cooling method could find its application in areas where conventional type of cooling is not possible and in those places where the area is small. The maintenance of these systems is also very easy. Also, this type of cooling arrangement is much safer to the environment as there are no harmful substances as in conventional refrigeration.

References

Christos N. Markides, Richard Mathie, Alexandros Charogiannis, (2016), An Experimental Study of Spatiotemporally Resolved Heat Transfer in Thin Liquid-Film Flows Falling Over an Inclined Heated Foil, *International Journal of Heat and Mass Transfer, Vol.93, pp.872-888.*

Yi Man, Hongxing Yang, (2015), Feasibility Investigation of The Low Energy Consumption Cooling Mode With Ground Heat Exchanger And Terminal Radiator, *Procedia Engineering, Vol.*121, pp.423-429.

Yoram L. Shabtai, John R.H. Black, (2014), Compact Hot Water Storage Systems Combining Copper Tube With High Conductivity Graphite and Phase Change Materials, *Energy Procedia, Vol.*48, pp.423-430.

Xiao Zhang, Li-Dong Zhao, (2015), Thermoelectric Materials: Energy Conversion between Heat And Electricity, *Journal of Materiomics,* Vol.1, pp.92-105.

D.M. Whaley, W.Y. Samana, A.T. Alemua, (2014), Integrated Solar Thermal System for Water and Space Heating, Dehumidification and Cooling, *Energy Procedia,* Vol.57, pp.2590-2599.

Camelia Stanciu, Dorin Stanciu, Alexandru Dobrovicescu, (2016), Effect of Greenhouse Orientation With Respect To E-W Axis on its Required Heating And Cooling Loads, *Energy Procedia,* Vol.85, pp.498-504.

Michal Pomianowski, Christian Hede Andersen, Per Heiselberg, (2015), Technical Potential of Evaporative Cooling In Danish And European Condition, *Energy Procedia,* Vol.78, pp.2421-2426.

N. Sangwaranatee and N. W. Sangwaranatee, (2015), The Study of Temperature Difference of Thermoelectric On Pic-Microcontroller, *International Journal of Information and Education Technology,* Vol.5, pp.656-659.

Prof. N. B. Totala, Prof. V. P. Desai, Rahul K. N. Singh, (2014), Study and Fabrication of Thermoelectric Air Cooling and Heating System, *International Journal of Engineering Inventions,* Vol.4, pp.20-30.

S. Kahl and W. Osikowicz, (2013), Composite Aluminum-Copper Sheet Material by Friction Stir Welding and Cold Rolling, *Journal of Materials Engineering and Performance,* Vol.22, pp.2176-2184.

Chakib Alaoui, (2011), Peltier Thermoelectric Modules Modeling and Evaluation, *International Journal of Engineering,* Vol.5, pp.114-121.

Pankaj Kumar Mishra, (2013), Experimental Study On The Cross Flow Air Cooled Plate Heat Exchanger Using Fin With Electric Pump, *International Journal of Engineering Trends and Technology,* Vol.4, pp.378-383.

Clinton Arendt, Trina Myers, and Jarrod Trevathan, (2014), Simulating House Cooling Methods to Decrease Energy Consumption by Creating Awareness And Attitude Change, *International Journal of Smart Home,* Vol.8, pp.177-190.

Poonia M.P., Bhardwaj A., Upender Pandel, Jethoo A.S., (2011), Design and Development of Energy Efficient Multi-Utility Desert Cooler, *Universal Journal of Environmental Research and Techology,* Vol.1, pp.39-44.

Daniele Ioli, Alessandro Falsone, Maria Prandini, (2015), Optimal Energy Management Of A Building Cooling System With Thermal Storage: A Convex Formulation, *9th International Symposium on Advanced Control of Chemical Processes*, *The International Federation of Automatic Control, 2015, Whistler, British Columbia, Canada,* pp.1151-1156.

Ronak Shah, Trupti Rathod, (2012), Thermal Design of Cooling Tower, *International Journal of Advanced Engineering Research and Studies,* Vol.1, pp.26-29.

Xiao Tang, Zhenhua Quan, Yaohua Zhao, (2010), Experimental Investigation of Solar Panel Cooling By A Novel Micro Heat Pipe Array, *Energy and Power Engineering,* Vol.2, pp.171-174.