Performance Evaluation of Thermoelectric Water Cooler and Heater

Rakesh Macharla, Dipak Bhoge, B. K. Sonage, S. S. Metan

Nagesh Karajagi ORCHID College of Engineering and Technology, Solapur, Maharashtra, India
Corresponding Author: Rakesh Macharla

***Abstract:* - Hot and cold water is always needed for human being; different systems are used to get hot and cold water. The devices which are available in market for heating and cooling purpose have more cost and size of those systems is more. e.g. refrigerator, electric heater and solar water heater. In this current paper, peltier effect is used to get cold as well as hot water simultaneously. The thermoelectric water cooler and heater (TEWC&H) consists of 6 thermoelectric modules (TEM) of specifications 12706 (where 127 represents number of pallets and 06 represents maximum ampere rating of the module) and two aluminum rectangular heat sinks with stainless steel water carrying tanks. The TEM were sandwiched between two water carrying tanks. This TEWC&H is used in two operating modes namely cooling mode and heating mode. The TEWC&H have features like no moving parts, long life, very reliable, do not emit harmful gases in environment and no maintenance. The minimum cold water temperature was found to be 10°C with mass flow rate of cold water 3.75 kg hr^{-1} and maximum hot water temperature as 60°C mass flow rates of hot water 3.75 kg hr^{-1} at an input power of 220 watts.**

***Keywords:* Peltier; heat sinks; cooling and heating; TEM; TEWC, TEWC&H**

Nomenclature

Q_c	**Cooling capacity in watts**
Q_h	**Heat rejected to hot side in watts**
m	**Mass flow rate of water in kg hr^{-1}**
Cp	**Specific heat of water = $4.18*10^3$ KJ $kg^{-1}K^{-1}$**
T_1	**Inlet temperature of water at cold side in K**
T_2	**Outlet temperature of water at cold side in K**
T_3	**Inlet temperature of water at hot side in K**
T_4	**Outlet temperature of water at hot side in K**
P	**Electrical power input= V*I in watts**
$(COP)_c$	**Coefficient of performance at cold side**
$(COP)_h$	**Coefficient of performance at hot**

I. INTRODUCTION

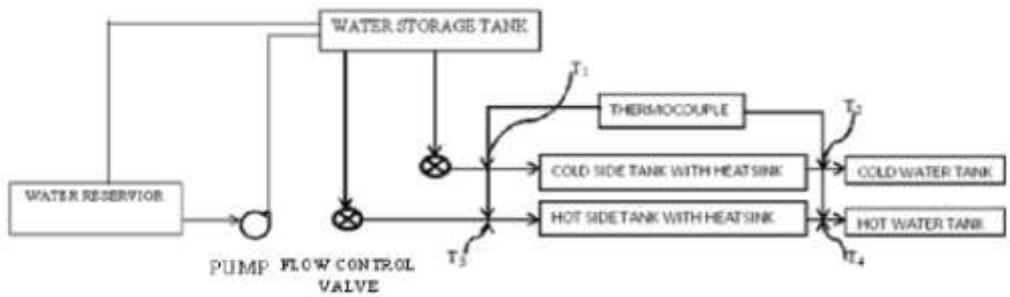
Thermoelectric modules (TEM) are semiconductor based electronic devices, which are like solid state heat pumps. These modules works on peltier effect. When a DC current flows through TEM, it transfers heat and maintains a temperature difference across the ceramic substrates causing one side of the module to be cold and the other side to be hot. The TEM consists of an array of semiconductor pallets that have been doped so that one of type of charge carrier either positive or negative carries majority of the current. The pairs of p and n type pallets are arranged so that they are connected electrically in series and thermally in parallel. The metalized ceramic substrates provides platform for pallets and the small conductive tabs connect them.

The performance of thermoelectric water cooler (TEWC) was studied and checked. The unit can cool water (3l) to 19.5°C & the corresponding cooling capacity is 90.33 W. The cooling performance of TEWC depends on the electrical power supply and heat rejected to the hot side heat exchanger [1]. Thermoelectric refrigeration (TER) technology is used to cool the car cabinet; thermoelectric (TE) cooling can lower the ambient temperature by 7°C.The air to air cooling can be used for personal cooling inside the car [2]. The railway coach cooling [3] has been implemented in the passenger railway in French railways, this technique has been implemented for 3 and half year period, for naval applications also this technology is used[4], The thermoelectric cooling dehumidifier are currently in use working on TER. They all found that TER is best suited for small capacity cooling and heating purpose with effective temperature control, in situations where lower power and smaller space are required. TER's are having wide range of applications as domestic refrigerators, portable coolers, compact heat exchangers, constant temperature baths, dehumidifiers [5], electronic devices cooling etc. The TE cooling has the capabilities to replace the conventional cooling technologies in future where lower power is the restriction. TE cooling devices can be powered directly by DC electric sources likewise PV cells, fuel cells, and DC batteries [7].

II. SYSTEM DESCRIPTION AND EXPERIMENTAL SETUP

The block diagram and actual system are shown in figure 1. The rectangular fins are used on both cold and hot side was made of aluminium. These two heat sinks were placed in stainless steel tank. The six TEM's of specification

12706(where 127 represents number of pallets and 06 represents maximum ampere rating of the module, manufactured by Hebei I.T., Shanghai Co., Ltd.) were sandwiched between two tanks. The thermal grease is applied to peltier module and the tank surface for proper contact. All TEM's are connected electrically in parallel. The mechanical flow control valves were used to change the flow rate of water in both the tanks. The steady flow rate of water level is maintained. The water is continuously flowing through the tanks with the maintained massflow rates. The setup operated in two different modes as cooling and heating modes. In cooling mode the flow rate of the water at the cold side is lower than that of the hot side and in heating mode the flow rate of the water at the hot side is kept lower than the cold side. The same flow rate is maintained in both the modes just by inter changing the pipe connections.



(a)

(b)

Figure 1(a) schematic sketch of experimental setup, (b) Photograph of experimental setup

III. EXPERIMENTAL METHOD

The mass flow rate of water is measured with uncertainty of ± 3.5%. The mass flow rate is adjusted by the flow control valves. A digital thermocouple is used to measure the temperature of the water. The thermocouple has the accuracy of ± 1°C. Two DC 1.5 V batteries are used to power the thermocouple. The temperatures are recorded at regular interval of 5 minutes. The data obtained by experiment is used to get the cooling capacity, heating capacity and COP.

The system analysis is performed by using first law of thermodynamics and following is the procedure adopted for analysis,

Heat rejected at hot side is given by,

Qh = (m Cp)h *(T4-T3)

Heat absorbed at cold side i.e. cooling capacity,

$Q_c = Q_h - P$

Where,

P = VI

Coefficient of performance is given by,

$(COP)_C = Q_c/P$

$(COP)_h = (COP)_c + 1$

IV. RESULTS & DISCUSSION

4.1 Temperature plot of hot and cold water for mass flow rates of hot water 3.75 kg hr^{-1} and cold water 46.73 kg hr^{-1}:

Figure 2(a) shows a temperature profile of hot and cold water with mass flow rate at hot side is 3.75 kg hr^{-1} and that of cold side is 46.73 kg hr^{-1}. The hot water temperature increased from 24.2 °C to 60.2 °C in 45 minutes. Meanwhile the cold water temperature decreased from 24.2°C to 23.9°C in 45 minutes. The maximum hot water temperature found to be 60.2 °C.

The temperature of hot water increases more than drop in temperature of cold water because in heating operation the heat rejected by the TEM is the summation of cooling capacity and the electrical supply given to thermoelectric modules.

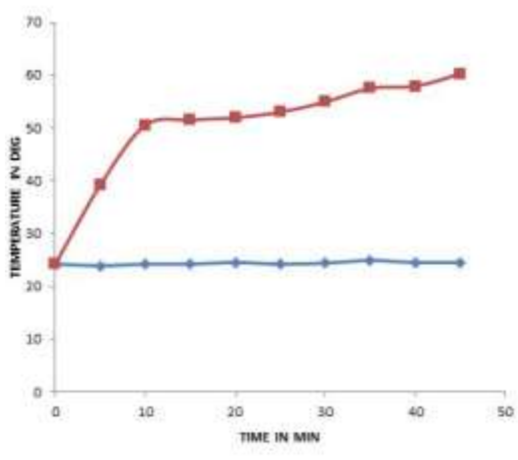


Figure 2(a) Temperature plot of hot and cold water for mass flow rates of hot water 3.75kg $hr^{-1}$and cold water 46.73kg hr^{-1}

4.2 Temperature plot of hot and cold water for mass flow rate of hot water 46.73kg $hr^{-1}$and cold water 3.75kg hr^{-1}:

Figure 2(b) shows a temperature profile of hot and cold water with mass flow rate of hot and cold water 46.73 kg $hr^{-1}$and 3.75 kg hr^{-1}respectively. The cold water temperature decreased from 24.2°C to 10°C in 45 minutes. Meanwhile the hot water temperature increased from 24.2°C to 27.4°C in 45 minutes. The minimum cold water temperature was found to be 10°C.

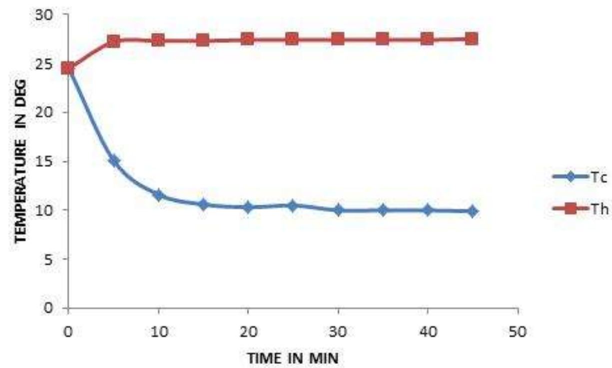


Figure 2(b) Temperature plot of hot and cold water for mass flow rate of hot water 46.73 kg $hr^{-1}$and cold water 3.75kg hr^{-1}

4.3 Performance of system for various input power supply:

The effect of varying the electric current on cold and hot side COP's are discussed below. The test was conducted for four different power supplies.

4.3.1 Performance of system for various input power supplies for mass flow rate of hot water 13.24kg $hr^{-1}$and cold water 99.72kg hr^{-1}:

Figure 3 (a) shows the plot of $(COP)_c$, $(COP)_h$ and $(COP)_{sys}$ with mass flow rate of hot water 13.24kghr^{-1} and cold water 99.27 kg hr^{-1}. The heating capacity increases with increase in power supply. Contrary the $(COP)_c$, $(COP)_h$ and $(COP)_{sys}$ decreases. The increase in heating capacity is less than the increase in power supply, therefore $(COP)_c$, $(COP)_h$ and $(COP)_{sys}$ decreases. The $(COP)_h$ decreased from 4.1176 to 1.1932 and heating capacity increased from 61.76 to 262.5 watt.

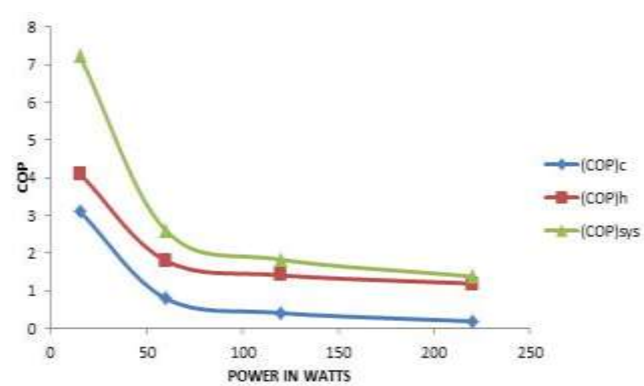


Figure 3(a) plot of $(COP)_c$, $(COP)_h$ and $(COP)_{sys}$ for mass flow rate of hot water 13.24kg $hr^{-1}$and cold water 99.27kg s^{-1}

4.3.2 Performance of system for various input power supplies for mass flow rate of hot water 99.72kg $hr^{-1}$and cold water 13.24kg hr^{-1}:

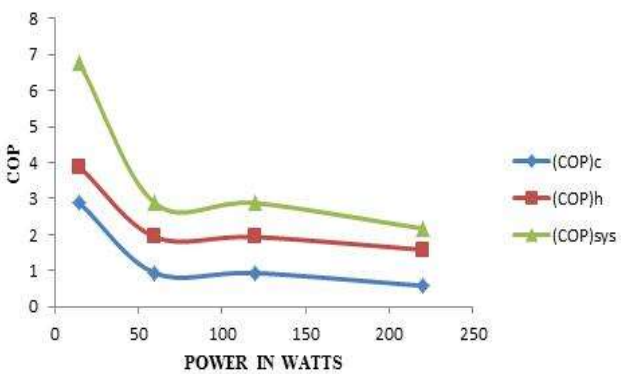


Figure 3(b) plot of $(COP)_c$, $(COP)_h$ and $(COP)_{sys}$ for mass flow rate of hot water 99.72 kg $s^{-1}$and cold water 13.24kg hr^{-1}

The change in cooling capacity is less than the increase in the power supply. The cooling capacities vary in between 43.17 W to 129.02 W and COP_c decreases from 2.8780 to 0.5865.

The system COP is defined as the summation of $(COP)_c$ and $(COP)_{h,}$

$COP_{sys} = COP_c + COP_h$

The COP_{sys} is always greater than COP_c and COP_h, the COP_h is always greater than COP_c this can be written as

$COP_{sys} > COP_h > COP_c$

The COP_{sys} decreases as input power to the TEM increases, because the increase in cooling and heating capacity is less than the increase in input power supply.

The COP of system is in the range of 2 to 7.The COP of the system is more as compared to heating or cooling system. Heat rejected by cold side is summation of cooling capacity and heat generated by electrical power input supply given to TEM. Therefore, the system is found to be more effective in heating mode

V. CONCLUSIONS

A thermoelectric water cooler and heater was constructed and tested. It shows that the TEWC&H can cool water up to 10°C and device can heat water up to 60°C at an input of only 220 Watts. The COP of system is in the range of 2 to 7 for mass flow rate of hot water 99.72 kg $hr^{-1}$and cold water 13.24kg $hr^{-1}$and for mass flow rate of hot water 13.24kg $hr^{-1}$and cold water 99.72kg $s^{-1}$with an input power supply of 220 watts. This system is more suitable for applications where heating as well as cooling is advised.

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