American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-11, Issue-02, pp-68-72
www.ajer.org
Research Paper Open Access

# Performance Evaluation of Indirect Evaporative Cooler

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***Abstract***

*Conventional air-conditioning systems utilize an excessive amount of total world power output thanexpected to rise further.The need to replace such old cooling systems in order to reduce electricity consumption that prompted the creation of the indirect evaporative cooler (IEC) system, which consumes very little power and produces no CFCs due to its use of pure water for cooling. The generic cell, piped to a humidifier, was built and insulated with appropriate materials. To transmit heat between the air, a counter-flow mechanism was utilized. Sensors were installed at the inlets and outlets of both channels to capture critical parameters such as temperature and humidity, which were then monitored by a microcontroller.The system's highest COP was 2.48, and its maximum cooling capacity was at 61 W with a 24.5 W power consumption. With a more significant temperature differential in the primary channel, more cooling capacity and COP might be attained.*

***Keywords:*** *Indirect evaporative cooler;Air-conditioning;Coefficient of performance; Energy*

Date of Submission: 05-02-2022 Date of acceptance: 18-02-2022

## I. INTRODUCTION

Air conditioning is a necessary component of modern living. In the last two decades, the development of space cooling systems has expanded. The mechanical vapor compression cycle is used in traditional space cooling technologies. Compressor, condenser, evaporator, and throttling valve are some of the essential components of this cycle. As a working fluid, a refrigerant is utilized [1].

Air conditioning equipment sales are predicted to increase by 10% from 2018 to 2019, resulting in increased air conditioning energy consumption. Energy demand has increased twofold since 1990, according to estimates. In 2019, almost 2 billion air-conditioning units generated 8.5 percent of total power. By 2030, more than two-thirds of all air conditioning systems will have been installed [2].

To conserve the environment and resources for the future, it is critical to solving the challenges posed by traditional air conditioning systems. Evaporative cooling is one of the energy-efficient and ecologically friendly options being investigated in space cooling. Direct and indirect evaporative cooling are the two basic types of evaporative cooling. Indirect evaporative cooling, the direct interaction of water and air, raises air humidity and reduces dry bulb temperature. However, this strategy may create discomfort due to the greater humidity level. In indirect evaporative cooling, dry and wet tubes separate the product air from the wet air [3].

Traditional air conditioning technologies have generated environmental and energy difficulties, and indirect evaporative cooling would be a comprehensive answer. Indirect evaporative cooling is currently a well-studied topic in building energy efficiency across the world. Through indirect evaporation, water is utilized to chill the external air. Water is less harmful to the environment than the refrigerants used in standard air conditioning systems. Evaporation of water is likewise a low-energy process [4].

Researchers create several indirect evaporative heat exchangers prototypes and test their effectiveness under various environmental/building conditions in experimental investigations.Fikri et al. [5]tested a multistage direct-indirect evaporative cooler utilizing a heat pipe and discovered that employing a heat pipe as a pre-cooler with a multistage direct evaporative cooler enhanced saturation efficiency, increasing relative humidity.Guo et al. [4]performed an exploratory study to assess the effectiveness of indirect evaporative cooling and found that the sensible heat transfer process in the primary air channel could only be evaluated using wet bulb effectiveness, the latent heat transfer difference could only be evaluated using latent heat efficiency and coefficient of enlargement, and the coefficient of performance could only be used to assess the effectiveness of the IEC.Antonellis et al. [6]investigated the performance of an IEC system by looking at the influence of plate shape on heat exchanger performance. The performance parameters of five distinct heat exchanger plate shapes were investigated. The rate of heat transmission and the surface's wettability was found to be dependent on the plate shape. When the overall heat transfer rate, surface wettability, and plate stiffness were considered, the reticular plate protrusion looked to be the best option. When water and secondary air ran in parallel, wet bulb efficacy was higher and pressure loss was lower than when they flowed in opposite directions.Wang et al. [7]experimented with a novel ceramic porous tube-type IEC under three different secondary air inlet cases (interior return-air, post-treatment primary air at outlet, and outdoor air). They found that the novel IEC saved 95 percent specific energy consumption, the coefficient of performance wad ranged from 20 to 34.9, the maximum achieved wet-bulb effectiveness was 40%, and the specific energy consumption was 1.1 kWh/h.

Because of the thin evaporating water layer, wet bulb efficacy increased with the increase in airflow rate, with an optimal value of 0.9, and wet bulb effectiveness improved as the spray water rate decreased after complete surface saturation. Meng et al. [8]conducted visual experimental research of condensation in a dry channel, concluding that condensation increased the temperature of the output primary air, total heat transfer, water feeding rate, and condensation rate while lowering the efficacy of the wet bulb. The shift from non-condensation to partial condensation occurred at 33.0°C and 50% relative humidity, respectively, while the transition from partial to complete condensation occurred at 35.0°C and 70% relative humidity. The maximum wet-bulb efficacy achieved was 80%.Min et al. [9]used experimental and computational approaches to examine primary air condensate behavior and IEC HT performance in dehumidifying conditions. The heat transfer efficiency of IEC for air conditioning systems may be improved by dropwise condensation. The total heat flow and heat transfer coefficient both increased due to the enhanced latent heat transfer. The maximum heat flux and heat transfer achieved were 1500 W/m2 and 200 $W/m^2$.C, respectively.

Because a literature study revealed that IEC technology created the foundation for this replacement, indirect evaporative technology can become a viable alternative to traditional air conditioning in buildings. The performance of IEC systems has improved dramatically due to breakthroughs in heat and mass transfer techniques, material optimization, and water spraying methodologies. In this study, the performance evaluation of the indirect evaporative cooler was measured.

## II. METHODOLOGY

The IEC setup was built, and multiple tests were conducted under various operating circumstances. This IEC design has three air stream channels separated by aluminum foil. The blower pushes outside air into the primary channel, which cools it down by transferring heat to secondary channels. A humidifier is essential in this situation. The humidifier is filled with water, and the line leading to the DC pump is dipped in it. The pump pressurizes the water and sent to the mist nozzle through a pipe.The humidifier receives primary air. The air stream is then humidified before being transferred to secondary routes at a low temperature.

Consider that the fluid flow is laminar and that the thermal effect is wholly developed since the channel gap is minimal compared to the length of the generic cell for calculating overall heat transfer. Various resistances represent thermal resistances of channels and aluminum foil.

Equation (1) can be used to get the overall heat transfer coefficient.

$$\frac{1}{\mathrm{U} \times \mathrm{A_s}} = \frac{1}{\mathrm{h_p} \times \mathrm{A_s}} + \frac{2 \times \delta_\mathrm{f}}{\mathrm{A_s} \times \mathrm{k_f}} + \frac{2}{\mathrm{h_s} \times \mathrm{A_s}} \qquad (1)$$

Equation (2) and Equation (3) can derive heat transfer coefficients for primary and secondary channels.

The coefficient of heat transfer for primary and secondary channels can be calculated by using Equation (3.3) and Equation (3.4) [10].

$$\mathrm{h_p} = \frac{0.023 \times ({}^{\mathrm{u_p}}/_{\mathrm{v_p}})^{0.8} \times \mathrm{Pr_p^{0.3}} \times \mathrm{k_p}}{\mathrm{D_p^{0.2}}} \qquad (2)$$

$$\mathrm{h_s} = \frac{0.023 \times ({}^{\mathrm{u_s}}/_{\mathrm{v_s}})^{0.8} \times \mathrm{Pr_s^{0.3}} \times \mathrm{k_s}}{\mathrm{D_s^{0.2}}} \qquad (3)$$

Equation (4) can be used to compute the Prandtl number:

$$\mathrm{Pr} = \frac{\mu \times \mathrm{c_p}}{\mathrm{k}} \qquad (4)$$

Based on a survey of the literature, the following parameters may be used to assess an IEC's performance:

The ability of an IEC to remove heat is referred to as cooling capacity. Because the heat removal process in the primary channel happens at a constant moisture level, cooling capacity is determined by temperature decrease in the primary channel[1]. Equation (5) can be used to calculate cooling capacity.

$$\dot{Q}_c = \dot{m}_p \times c_p \times \Delta T_p \tag{5}$$

Equation (6) is used to compute the total heat transfer rate for a heat exchanger[11].

$$\dot{Q} = U \times A_e \times T_{LMTD} \tag{6}$$

Equation (7) computes the log mean temperature of a counterflow heat exchanger.

$$T_{LMTD} = \frac{(T_{p,o} - T_{s,i}) - (T_{p,i} - T_{s,o})}{\ln\left(\frac{T_{p,o} - T_{s,i}}{T_{p,i} - T_{s,o}}\right)} \tag{7}$$

Wet bulb effectiveness $\varepsilon_{wb}$is a metric that relates to the degree to which the main air outlet temperature approaches the secondary air input wet bulb temperature [1]. Equation (8)can be used to compute it.

$$\varepsilon_{wb} = \frac{T_{p,i} - T_{p,o}}{T_{p,i} - T_{s,wb}} \tag{8}$$

Dry bulb effectiveness $\varepsilon_{db}$as defined in Equation (9), is the ratio of the difference between primary air inlet outlet temperatures to the difference between primary air intake dy bulb temperature and secondary air inlet dry bulb temperature[1].

$$\varepsilon_{db} = \frac{T_{p,i} - T_{p,o}}{T_{p,i} - T_{s,i}} \tag{9}$$

Compared to traditional air conditioning systems, indirect evaporative coolers use less energy. For fluid circulation, blower and a pump are employed in this IEC. Equation (10) can compute the total power utilized by the IEC.

$$P = P_{p,b} + P_{s,b} + P_{pu} \tag{10}$$

The coefficient of performance (COP) is IEC's cooling capacity ratio to its overall power consumption. It represents the cooling system's energy efficiency as indicated in Equation (11) [1].

$$COP = \frac{\dot{Q}_c}{P_{p,b} + P_{s,b} + P_{pu}} \tag{11}$$

## III. RESULT AND DISCUSSION

The suggested generic cell was built and tested under a variety of situations. The influence of operating factors on IEC generic cell performance in the supply air, such as cooling capacity, total heat transfer, wet bulb, dry bulb efficacy, power consumption, and coefficient of performance, was investigated.Experiments were carried out successfully on the constructed innovative type IEC system under various operating circumstances. The primary and secondary air velocities were 5 m/s and 2 m/s, respectively, and the flow rate in the humidifier was 2.7 LPM at a constant pressure of 101 kPa throughout all trials.

Table 1. Heat transfer co-efficient and Prandtl number

| Parameter | Value | Unit |
|---|---|---|
| $h_p$ | 35.21 | W/m$^2$-K |
| $h_s$ | 17.43 | W/m$^2$-K |
| U | 6.986 | W/m$^2$-K |
| $Pr_p$ | 0.7456 | - |
| $Pr_s$ | 0.7477 | - |

Most air's thermo-physical qualities (heat capacity, conductivity, density, and viscosity) may alter when temperature and relative humidity change. So, using EES, the thermophysical characteristics of air are estimated for each temperature and relative humidity value, however there is a tiny difference in these properties. All other derived parameters required to assess outcomes are listed in Table 2 below.

**Table II.** Calculated parameters

| Description | Symbol | Value | Unit |
|---|---|---|---|
| Surface Area | $A_s$ | 0.504 | m$^2$ |
| Cross sectional area | A | 0.001 | m$^2$ |
| Effective area of HX | $A_e$ | 1.008 | m$^2$ |

| | | | |
|---|---|---|---|
| Hydraulic diameter | $D_p$ | 0.006914 | m |

Following a successful test run, experimentation was initiated to evaluate the IEC's performance. Table 3 displays the results.

**Table2.** Experimental results

| $\Delta T_p$ | COP | P |
|---|---|---|
| (℃) | - | (W) |
| 10.1 | 2.48 | 24.508 |
| 8.5 | 2.10 | 24.508 |
| 7.7 | 1.89 | 24.508 |
| 7.2 | 1.76 | 24.508 |

Its coefficient of performance measures a cooling system's efficiency. The coefficient of performance is calculated by the ratio of the quantity of energy used and the cooling capacity. Air blowers and a pump were installed in the proposed IEC system, consuming a total maximum electric power of 24.5 W during all experiments while the cooling capacity gradually increased. As the cooling capacity increased over time, so did the coefficient of performance, eventually reaching the maximum achievable value of 2.48. As it approached its limits, the proposed system could not achieve a higher coefficient of performance. Figure 1 depicts the gradual increase in the coefficient of performance withincreased cooling capacity.

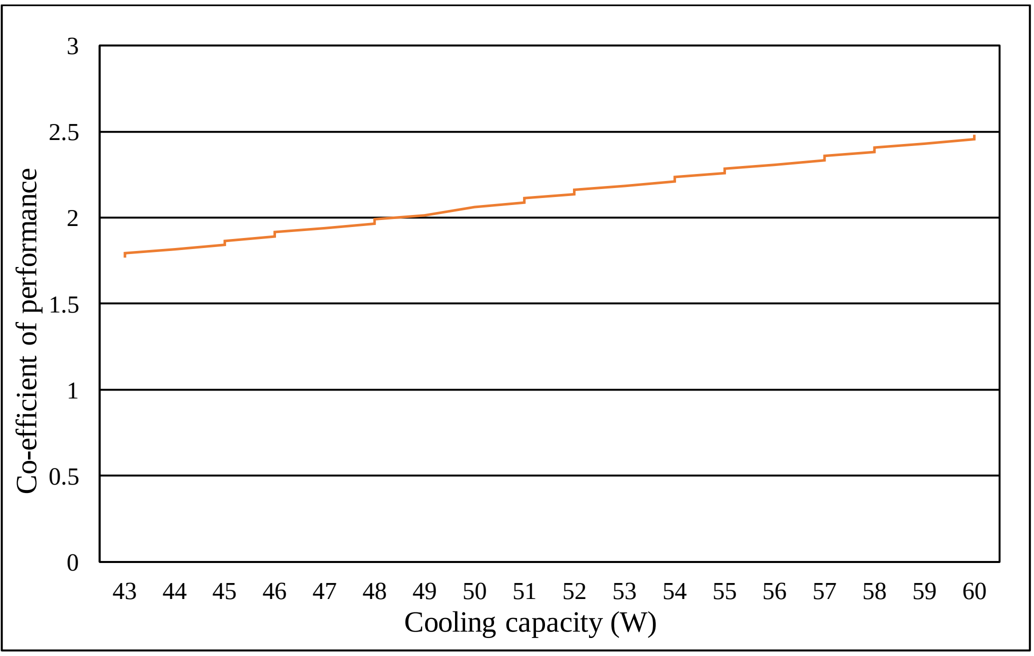

Figure 1.Coefficient of Performance with respect to cooling capacity

It was also found that as the temperature difference between the air in the primary channel increased, so did the coefficient of performance. The increase in the coefficient of performance was caused by the fact that as the temperature difference in the primary channel increased, so did the cooling capacity, increasingthe coefficient of performance. Figure 2 depicts the increase in the coefficient of performance with increasing temperature differences in the primary channel.

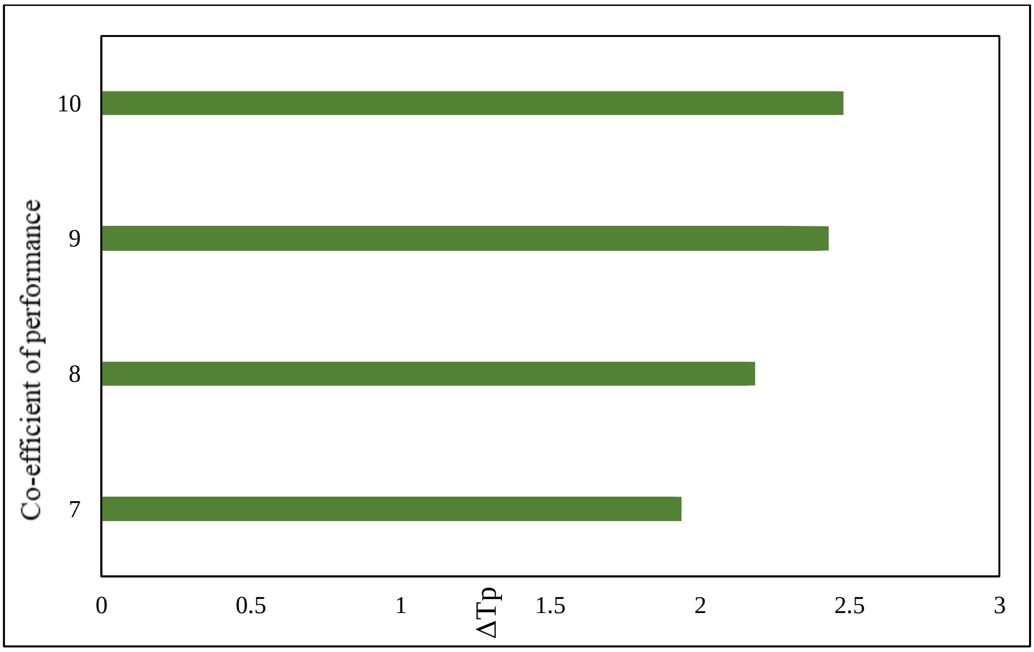

Figure II.Coefficient of Performance with respect to temperature difference.

## IV. CONCLUSION

A generic cell was built to test the performance of an indirect evaporative cooler. The test apparatus consists of a humidifier and a general cell with three parallel primary and secondary air channels flowing in opposite directions. This IEC has three air stream channels, divided by aluminium foil. Two auxiliary channels surround the primary channel. Water is not sprayed directly on channels in this IEC setup. In another chamber, the air is humidified before being pumped into the secondary channels. Thermal resistance is extremely low in thin aluminum foil. When the primary air temperature difference is 10.1°C, the maximum attainable COP is 2.48. The coefficient of performance (COP) rose as the temperature differential of the primary air grew, but the power consumption remained constant at 24.5W. The IEC's cooling capability may be improved by increasing the number of cells.

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