DEW POINT EVAPORATIVE COOLER (DPEC): RECENT DEVELOPMENTS AND APPLICATIONS

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ABSTRACT

Dew point evaporative coolers (DPEC) have two salient features. They are the ability to cool the air close to the dewpoint temperature and the saturation of the air with moisture. Thus, DPECs find several innovative applications for cooling, heating and the efficiency improvement of the power cycles. In this paper, we will discuss the fundamental aspects of DPEC including the thermodynamic model and simulation followed by recent developments such as irreversibility losses and hybridization. Some innovative applications of DPECs and its hybrids for the cooling of PV panels, desalination and power generation in the Inverted Brayton Cycle (IBC).

KEY WORDS

Indirect Evaporative Cooler, PV thermal, Desalination, Dehumidification.

1. INTRODUCTION

Indirect evaporative coolers (IEC) can cool down the supply air to or close to the dewpoint temperature. Thus, these systems are also called dew point evaporative coolers (DPEC). Direct evaporative coolers, on the other hand, are limited to the wet-bulb temperature. In IECs, a portion of the saturated air in the dry channel is directed to the wet channel for the evaporation of water. This air, the working air, is discharged out of the wet channel at higher moisture content. Thus, IECs are often utilized for the air saturation processes, particularly, in the power cycles such as Inverted Brayton Cycle (IBC) for the improved combustion process. The simultaneous cooling and air saturation features of the IEC are ideal for desalination.

2. DESCRIPTIONS OF AN IEC

2.1 Basic principles

Figure 1 shows the processes involved in an IEC on the psychometric chart. Hot dry intake air is cooled in the dry channel because of the evaporation of the water in the wet channel initiated by the vapor pressure difference. A certain portion of this intake air is extracted as the supply air at the end of the dry channel, where the remaining air is diverted into the wet channel as the working air. This working air exits the wet channel with high moisture content.

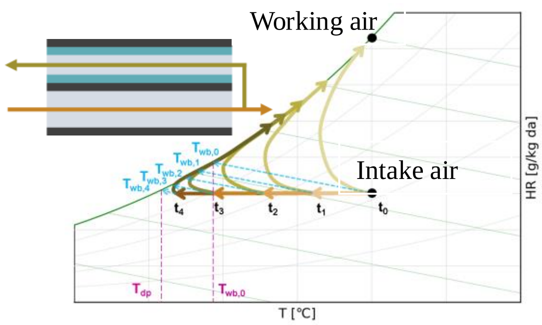

Fig.1: Working paths of the air streams involved in an IEC

2.2 Mathematical model

The transient model of the IEC is shown in Fig. 2. The model includes the mathematical equations for the channels, water film and channel plate.

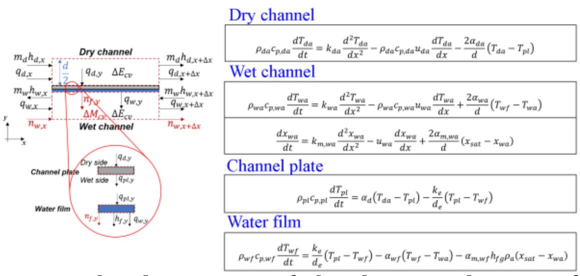

Fig.2: The description of the discrete element of IEC and the mathematical model

The thermodynamic models for the second law analysis of the IEC are described in Fig. 3.

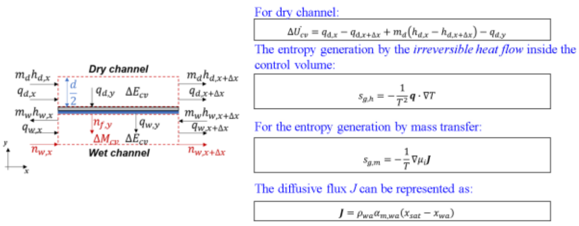

Fig.3: The entropy generation models of and IEC

3. RECENT DEVELOPMENTS AND APPLICATION OF IEC

3.1 Performance improvement of IBC

The cooling and air saturation features of the IEC are exploited to improve the thermal efficiency and specific work output of the inverted Bryton cycle. The current cycle increases the thermal efficiency from 8.13% to 14.36% (76.63% improvement), while exhibiting 20.08% increase in the specific work output when comparing to a conventional air-cooling IBC cycle[1,2].

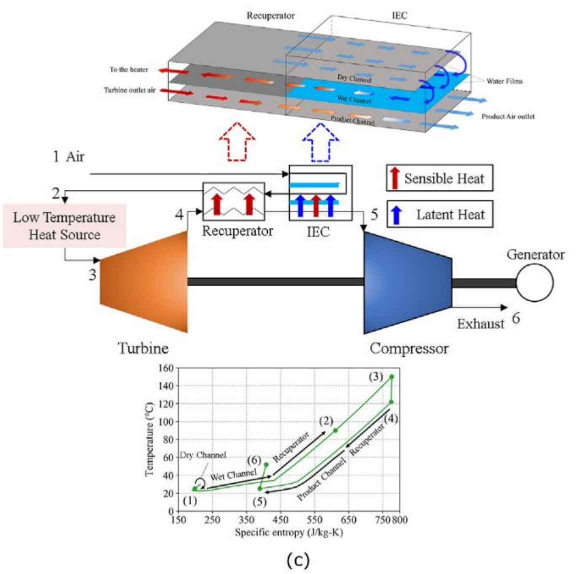

Fig. 3: Heat and mass exchanger using an IEC for IBC

3.2 Desalination using the IEC

The IEC systems can provide cooling and air saturation. And the system can achieve these features simultaneously and effectively. The features are utilized for the desalination of sea water[3].

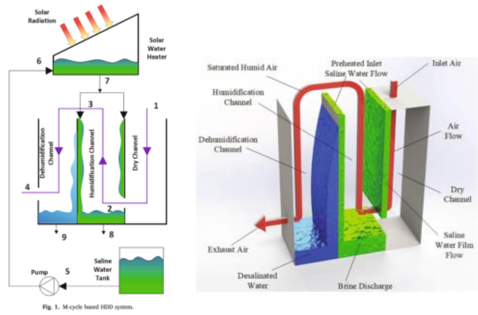

Fig.4: Water desalination using the features of cooling and air saturation achievable in the IEC

Based on the second law analysis, although the efficiency of the M-cycle based HDD system improves at higher ambient air temperature and humidity ratio, the system performs best within a temperature range of 35 °C to 45 °C and humidity ratio range of 15 g/kg to 25 g/kg.

3.3 Performance improvement of the PV using IEC

Performance of a typical PV panel is often hindered by the limitations of the heat rejection to maintain the panel at low temperatures. Conventional cooling systems like air-cooling and direct evaporative coolers are unable to bring down the temperature of the solar panel effectively. Figure 5 shows the PV panel cooling system using a "true IEC"[4-6].

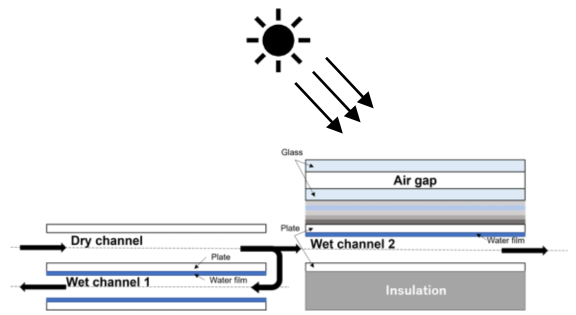

Fig.5: PV panel cooling the IEC for the improved efficiency

In this configuration, a wet channel has been added at the back of the PV panel. The supply air from the upstream IEC, which is at the near saturation condition passes through this wet channel. Such a novel configuration provides significant cooling effect for the panel. As compared to the conventional air cooling, the proposed system is able to reduce the temperature of the panel to around 47 °C from approximately 75 °C. The maximum solar cell efficiency can reach 16.7% based on the weather data of 1st June, about 16.4% higher than that with the sensible air cooling; the minimum value of the solar cell efficiency is 15.3%, 1.9% higher compared to sensible air cooling.

4. CONCLUSIONS

Indirect evaporative coolers (IEC) offer two salient features namely: the supply air at or near dewpoint temperature and air saturation of the working air.

Moreover, the system produces them simultaneously. Several engineering applications can utilize these features for the performance improvement. We have demonstrated several such systems for power generation, desalination and PV panel cooling. Developments in the pipeline includes IEC for heating, dehumidification and a few more.

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