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Field Performance of Dew Point Cooling for Edge Data Centre with Evidence from a UK Operational Case

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ABSTRACT

Edge data centres and small server rooms are widely embedded in non-domestic buildings, yet their cooling systems remain energy intensive and under-optimised. This study reports the operational evidence of dew-point cooling (DPC) in a live edge data centre in Hull, the UK. The units feature a heat and mass exchanger, high-performance wetting medium, and intermittent water supply. Results from representative operating periods showed that the DPC system delivered stable cooling with low electrical input, achieving a Coefficient of Performance (COP) of up to 40. The monitored hourly profiles also showed important maintenance periods, with a legionella monitoring scheme as a routine risk management. These findings provide evidence to demonstrate that the DPC system is an efficient and practical cooling solution for small edge data centres and support its wider application in similar built environments.

Keywords: Edge data centre; Dew point evaporative cooling; Energy Efficiency; Field performance

1. INTRODUCTION

1.1 Energy efficiency challenges in small-scale edge data centres

The energy efficiency of small-scale edge data centres (EDCs), including server rooms and facilities below 500 kW, is becoming an important issue [1]. These sites are widely embedded in commercial, institutional, and industrial buildings, and their numbers are growing rapidly with the expansion of AI and digital services [2]. Although individually small, their collective energy and carbon impact is significant.

Small EDCs are not well regulated compared to larger facilities. The revised EU Energy Efficiency Directive (2023/1791) only requires reporting for data centres above 500 kW, leaving sub-500 kW sites outside mandatory coverage [3]. Yet recent EU reporting shows that very small (100 – 500 kW) and small (500 – 1000 kW) centres already represent a large share of the stock, with average Power Usage Effectiveness (PUE) values around 1.6 or above, much higher than hyperscale sites (lower to 1.2) [4].

Similar challenges are observed worldwide. In the US, many small EDCs are located in offices, hospitals, or retail buildings and consume around 13 TWh/year, emitting 7 $MtCO_2e$ [5]. In China, one university study found that cooling alone accounted for nearly half of total IT room energy use [6].

Collectively, these findings underline a regulatory and research gap that is the small EDC facilities are widespread, but they can be energy inefficient, and insufficiently studied. This makes the EDC cooling a critical frontier for targeted efficiency and decarbonisation solutions.

1.2 Evaporative cooling and the advances in dew-point cooling for data centres

Evaporative cooling lowers air temperature by using the latent heat of water evaporation. In terms of the direct evaporative cooling (DEC), air passes through wetted surfaces, reducing temperature but increasing humidity. In indirect evaporative cooling (IEC), however, supply air is cooled by a heat exchanger, while a secondary air stream is cooled by evaporation. This avoids adding moisture, but the lowest supply temperature is limited to the wet-bulb value. Dew-point cooling (DPC) is a similar form of IEC, but a slightly more complex scheme. It uses a heat and mass exchanger integrated with dry and wet channels. As shown in Figure 1, part of the working air is diverted through perforated

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plates to the wet channel, where it evaporatively cools and flows in reverse direction. This enables the product air, flowing in adjacent dry channels, to be cooled below the wet-bulb temperature and close to the dew-point temperature of the incoming air.

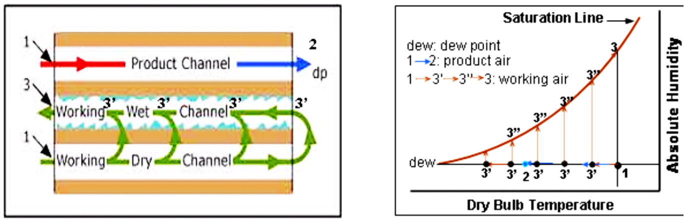

Figure 1 Principle of dew point cooling [7]

The authors and the research group have carried out a series of studies on the dew point cooling technology (European Patent Register EP3526537). In earlier laboratory work, the team designed and tested several DPC prototypes. The team introduced a list of technical innovations that remain central to the DPC design including [8,9]:

- A heat and mass exchanger using a counter-current flow pattern based on a hybrid structure of flat and corrugated plates increased heat and mass transfer area by approximately 40% compared with flat-plate designs, while reducing airflow resistance by 50–56%;
- A high-wicking fabric layer ensured water absorption, evaporation rate, and durability, while providing antibacterial capability; and
- Instead of continuous wetting, pulsed water delivery reduced water use, improving energy efficiency of the water pump.
- Prototype systems were progressively scaled up and tested. A prototype achieved a coefficient of performance of 52.5 under ASHRAE Standard 143.

1.3 Research gaps

Although the DPC technology has demonstrated high efficiency in earlier laboratory studies, two important research gaps remain.

1.3.1 Favourable test conditions were used in laboratories

The previous prototype evaluations were carried out under ASHRAE Standard 143 or similar hot-dry conditions. For example: Xu et al. tested a DPC prototype at a dry-bulb temperature of 37.8 °C and wet-bulb temperature of 21.1 °C [9]. Duan used 35 °C dry-bulb / 24 °C wet-bulb in exchanger tests [7]. These conditions create a large dry-bulb and wet-bulb temperature difference $\Delta T \approx 17$ °C, which is favourable for evaporative systems. In contrast, humid maritime climates such as the UK rarely reach such hot-dry conditions. Typical summer design values are dry-bulb 26 °C, wet-bulb 19–21 °C, giving a much smaller ΔT of only 5–7 °C. This reduces the cooling potential and means laboratory results do not fully represent real operation in small edge or server-room data centres in Europe.

1.3.2 Lack of long-term operational evidence

Previous demonstrations have been short-term, often limited to a few months. The studies confirmed technical feasibility, but did not capture seasonal variation, component durability, or water quality issues. As a result, the long-term sustainability and reliability of DPC in edge data centres remain unknown.

1.4 Contributions of this study

The present study addresses gaps that earlier work could not resolve. It provides the operational evidence from a sub-500 kW edge data centre in the UK, based on typical day data in 2022. Results evaluate cooling performance under a humid climate. The study also reports on Legionella monitoring and maintenance, confirming safe operation.

2. MATERIAL AND METHODS

This study was conducted in a edge data centre located in a non-domestic building in the UK (location Bridgehead Business Park, Meadow Rd, Hull, Hessle HU13 0GD). The facility is representative of a small-scale server room. Cooling was provided by two DPC units, which was installed alongside the existing wall-mounted split-type air conditioning (AC) units used as the baseline system. The DPC unit comprised a heat and mass exchanger, a wetting medium, and variable speed fans. It delivered cooled supply air through ducting to the server room and operated under normal IT loads (Figure 2). The baseline wall-mounted AC units were direct-expansion (DX) systems with compressor cooling, commonly used in small server rooms.

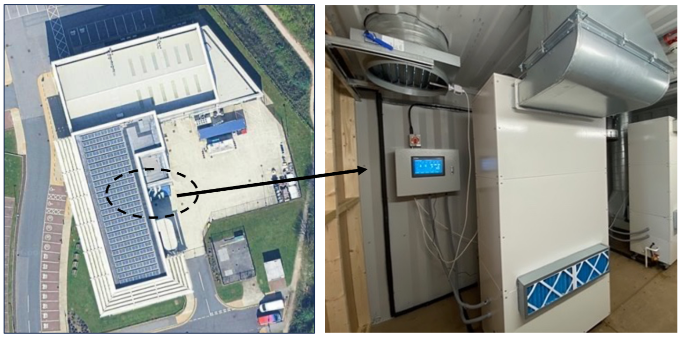

Figure 2 The DPC units at AIC in Hessle HU13 0GD

Performance data were monitored during 2022. For this paper, results are presented for typical days. The following parameters were recorded:

- Supply air temperature (°C) at the DPC outlet.
- Return air temperature (°C) at the DPC inlet.
- Electrical power consumption (kW) of the DPC unit and the wall-mounted AC.
- Air flow rate (m^3/h) through the DPC supply duct.

From these measurements, the following performance indicators were calculated:

- Cooling capacity (kW): calculated from airflow and supply/return temperature difference.

$$Cooling\ capacity = \underbrace{\dot{m}_a}_{air\ flow\ rate} \times \underbrace{c_p}_{air\ specific\ capacity} \times \underbrace{\left(T_{return} - T_{supply}\right)}_{dry\ channel\ temperature\ difference}$$

- Coefficient of performance (COP): ratio of cooling capacity to electrical input power.

$$COP = \frac{Cooling\ capacity\ (kW)}{DPC\ power\ consumption\ (kW)}$$

Apart from monitoring the energy performance, ensuring safety operation is critical. Because DPC involves evaporative processes, water quality management is a critical part of safe operation. Evaporative cooling systems can provide a potential environment for legionella bacteria, which are associated with legionnaires' disease. Tests were conducted using dip-slide culture methods, which provide an indication of bacterial growth in the circulating water. The dip-slides were incubated at 30 °C for 48 hours and visually inspected to detect bacterial colonies. Incubation at constant temperature and duration is important because variations can lead to false negatives or overgrowth and misleading results. This aligns with Health and Safety Guidance (HSG274) guidance for water systems [10].

3. RESULTS

Continuous measurements have been collected since 2022, covering seasonal and operational variations under real IT loads. In this paper, representative findings are presented. Figure 3 shows the hourly performance of the DPC unit on 15 January 2022. The cooling capacity followed the variation of the server room load, reaching around 4 kW on average, with higher peaks when the IT demand increased in the morning. During the afternoon, the cooling demand gradually decreased, and the capacity reduced accordingly. The COP remained stable between 22 and 28. The input power of the DPC unit was generally around 0.1 kW, but fluctuated between 0.1 and 0.26 kW. These short-term peaks were linked to the intermittent operation of the water pump, which periodically circulated water to maintain wetting of the exchanger surface.

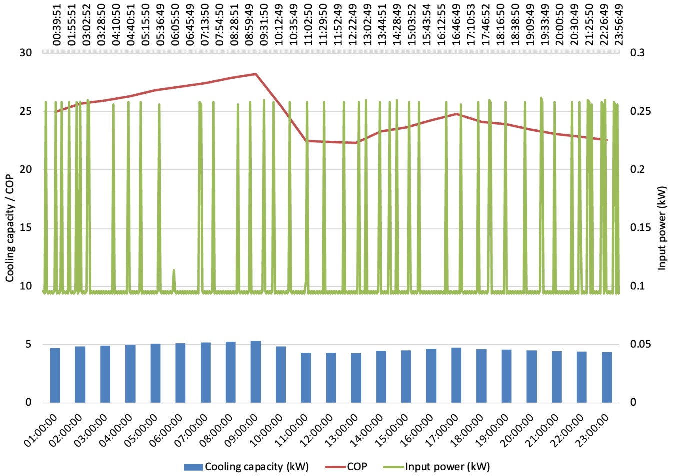

Figure 3 Hourly DPC performance data on a typical winter day

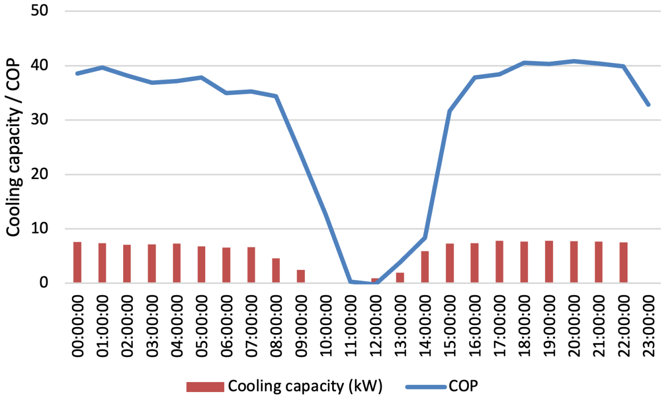

Figure 4 Hourly data showing DPC on scheduled maintenance

Figure 4 presents another typical operation profile, where the COP fluctuated between 32 and 40 for most of the day. However, two consecutive hours recorded COP = 0. This was not due to system failure but to a scheduled cleaning cycle. During this cycle, the unit was switched off, drained, and disinfected as part of the Legionella management protocol. Such cleaning ensures safe operation of evaporative systems by reducing biofilm and bacterial risk.

In addition to its relatively low and stable power use, the DPC system operates without refrigerants. This eliminates the risk of refrigerant leakage, which is a significant contributor to global warming potential (GWP) in conventional compressor-based systems. But it introduces legionella risk in operational consideration. A legionella management scheme has been implemented during the tests. Figure 5 shows a result on 7 September

2022. The colonies observed were light, indicating good water hygiene control. Dip-slide tests (30 °C incubation for 48 h) were performed in the study. When combined with routine cleaning and disinfection cycles, these results confirmed that the DPC system can be operated safely over long periods.

Figure 5 Dip slide results on 7 September 2022

4. CONCLUSIONS

This study presented a dew point cooling system in a live edge data centre under UK conditions. Based on monitored hourly data, the system demonstrated efficient cooling performance under operating conditions. On the representative days presented, the DPC unit provided cooling with low electrical input. The hourly profiles also showed the system performance with scheduled cleaning and maintenance events. This is important because it demonstrates not only high energy efficiency, but also the practicality of integrating DPC into routine facility operation. Future work will report the broader long-term operational characteristics.

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