A Super Performance Dew Point Cooler for Data Centre

Summary

This project aimed to design, construct, install, and demonstrate a 100 kW super performance dew point cooling system at a live data centre to remove the tremendous amount of heat dissipated from the IT equipment and maintain an adequate space temperature in the data centre. The dew point cooling technology, a form of indirect evaporative cooling, cools the air using the principle of water evaporation, leading to significant energy savings and enhanced temperature reduction compared to conventional indirect evaporative cooling technologies. The super performance dew point cooler in this project stands out with significantly improved energy efficiency compared to other evaporative cooling similar technologies, thanks to a series of technological breakthroughs.

The performance of the dew point cooling system was monitored and compared with the existing conventional vapour compression air conditioning system at the demonstration site. The project lifted the technology readiness level from TRL6 to TRL8 by demonstrating the technology in an operational environment. This case study is directly relevant to data centre space cooling. The technology is also compliant with other types of building cooling.

The Industrial Energy Efficiency Accelerator (IEEA)

The IEEA programme supports the development of innovative technologies that will help industry reduce energy consumption and cut carbon emissions. It focuses on innovations with large potential cross-sector energy and carbon reduction impact - either new technologies or established technologies applied to new sectors. Over £15 million in public and private funding has been committed to develop solutions through partnerships between technology developers and industrial companies willing to test technologies on-site. The programme is funded by the UK government (BEIS) and managed by the Carbon Trust, with support from Jacobs.

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Introduction

With over 15-years' continuous endeavour, the University of Hull (UHULL) has developed a super performance dew point cooler which has significantly improved efficiency, i.e. coefficient of performance (COP), compared to existing technologies. This significant breakthrough has resulted from a series of technological innovations including: the hybrid flat/corrugated heat and mass exchanger; the high water absorptive and diffusive wet material; the well-tuned water pressure and flow rate; and the optimised fan configurations. The dew point cooler achieves a much higher COP (up to 40) than the existing vapour compression air conditioning system widely used in data centres (COP of 2-3). Using the dew point cooler for data centre cooling can significantly reduce electrical energy consumption and carbon emissions. The demonstration results showed 90% energy saving and carbon reduction achieved at the Maritime Data Centre in Hull.

The IEEA has been providing the project consortium with comprehensive support throughout the project including funding, project management, demonstrator installation, and performance measurements. The available funding has allowed the project consortium to demonstrate and qualify the specialist dew point coolers in a live data centre environment and brings together the experts from the university, manufacturer, and data centre operator to complete the technology transfer and engineering applications. The programme provided us with high-level, high-quality project management from the IEEA team, which helped the project consortium to effectively manage the daily actions and tackle difficulties in the project.

About the innovation

The dew point cooling process is based on indirect evaporative cooling and the M-cycle principle. During the operation, the intake air flows into the dry channels of the heat exchanger. Air moves forward along the dry channel and loses heat to the adjacent wet channels, owing to the temperature difference established between the dry and wet channels and water evaporation on the wet channel wall. At the end of the dry channel, the air is divided into two parts. One fraction of the air flow, i.e. the product air, is delivered into the conditioned space for cooling. The other fraction, namely the working air, is diverted into the adjacent wet channels for water evaporation. Within the wet channels, the working air moves backwards, absorbing the heat transferred from the dry channels and receiving the moisture evaporated, thus completing a heat and moisture transition process from one part of air to another. The super performance dew point cooler comes with several innovations, the most significant being the novel complex heat exchanger which comprises numerous shape-changing heat and mass exchanging sheets (Figure 1). Each sheet is in a corrugated shape in the main heat transfer area to increase the heat transfer area and rate between the dry and wet channel air. Additionally, there is a flat area in the air flow entry and exit portions for water and air distribution. This structure increases the heat transfer area and heat transfer rate by around 40% compared to the traditional flat plate heat exchanger. It also removes the triangular air guides of a flat plate heat exchanger, , therefore, reducing the air flow resistance across the channels by around 50%.

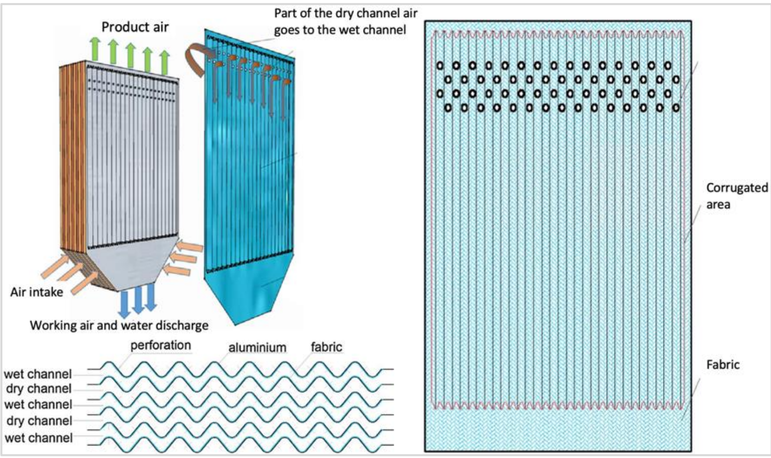

Figure 1 Novel complex heat and mass exchanger

The demonstration

The demonstration site – Maritime Data Centre

A novel dew point cooling system with ten 10 kW (total 100kW) modular cooling units was designed, constructed, and installed at the Maritime Data Centre in Hull city centre. Considering the limited indoor space, the demonstrator cooling system was installed externally. The cooling units are designed and constructed in a modular format to maximise the installation flexibility. The project consortium designed an air ducting system to bring the cooled air from the external demonstrator cooling system into the indoor environment (Figure 2).

Figure 2 (a) External ducts and coolers, (b) internal ducts and servers

Key project activities

The key project activities included (1) data centre site survey to obtain the cooling load, cooling energy management, and system installation method; (2) dew point cooler design including detailed numerical simulations, development of engineering design strategy, and modular structure design; (3) heat exchanger and water distributor manufacturing, component purchasing (fans, pumps, and control kits), cooler construction and performance testing in an environmental chamber before the installation (Figure 3); (4) installation and commissioning of the dew point cooling system; and (5) testing and monitoring.

Figure 3 (a) Performance testing in environmental chamber, (b) commissioning after the installation

Performance optimisation and monitoring

Figure 4 Demonstrator test runs: (a) UHULL researcher adjusting the demonstrator settings, (b) an engineer adjusting the existing air conditioners

The dew point cooling system installed at the Maritime Data Centre was tested and monitored. To ensure the cooling system reached the optimised operation, the project partners worked together in testing the dew point cooling system under various settings (Figure 4). A series of settings were updated to enable the cooling system to reach the optimal performance including the fan speed for the best working air ratio, water pump operation intervals for the minimum power consumption, as well as updating the control box display and data collection schemes. After the testing, the project moved to the monitoring stage where the dew point coolers supplied cooling air into the data centre while the existing vapour compression air conditioning system (the baseline) of the data centre acted as standby. It was necessary to operate in this manner to provide assurance to the data centre manager that cooling would be uninterrupted should there be a fault with the dew point coolers. Thus the existing air conditioning units took up part of the cooling load, which reduced the cooling capacity for the demonstration equipment. Temperature and humidity sensors were used to measure the performance of the demonstrator cooling system and the indoor air conditions. The measurements were used for system performance evaluation including the cooling capacity and COP. Control boxes were installed to display the real-time cooler performance. A remote monitoring system was also set up to measure the indoor air temperature and energy usage of the existing air-conditioning units.

Results

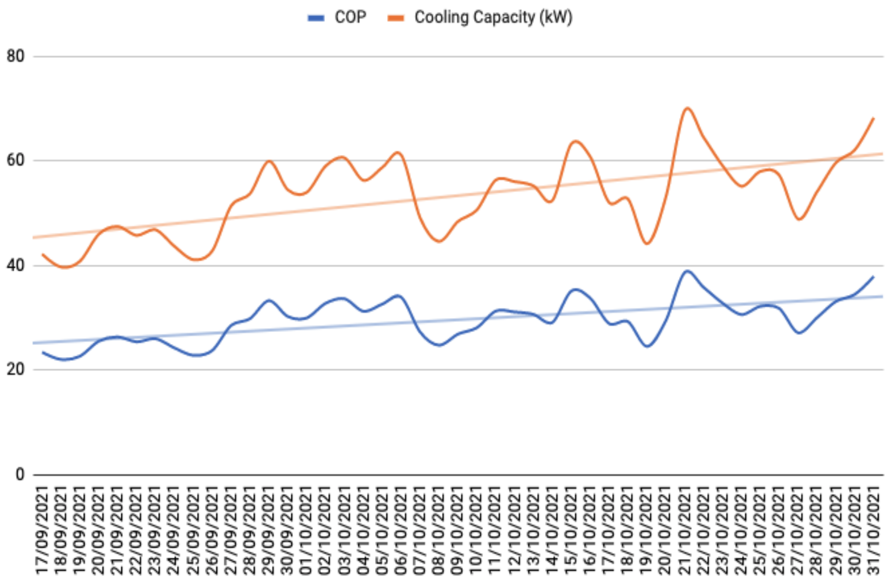

Figure 5 Cooling capacity and COP

The demonstrator dew point cooling units operated continuously for six weeks from 17/09/2021 to 31/10/2021. The units performed stably without equipment failure during the monitoring stage. The equipment is constructed with a minimum number of moving parts and the project partners conducted extensive equipment commissioning and test runs before the trials. The monitoring results and findings are highlighted as follows.

- The system was highly energy-efficient for cooling at the demonstration site. The dew point cooling system provided an average cooling capacity of 53.5 kW, average power consumption of 1.8 kW, average

COP of 29.7, and maximum COP of 48.3 (Figure 5). The average COP of 29.7 is smaller than the target 40 because the existing air-conditioning units took up part of the cooling load.

- The indoor air temperature ranged from 18 °C to 25 °C and the indoor relative humidity ranged from 55% to 78%, which align with the ASHRAE recommendations for data centres (18-27 °C and 20-80% relative humidity).
- By using the dew point cooling system, the average power consumption of the existing air conditioning system at the demonstration site was reduced from 35.5 kW to 1.8 kW. By simulating the dew point cooling system performance throughout a year at the demonstration site using a validated model, the average annual COP of the cooling system is 37.8 with a cooling capacity of 70 kW and average power consumption of 1.9 kW. Applying the dew point cooling system can reduce the cooling energy consumption by over 90%.
- For the demonstration cooling units, a part of the cooling effect is driven by water evaporation. The water usage for the units' evaporative cooling is around 400 L/day. Considering the charge of water and sewerage of £4.1/m^3 according to Yorkshire Water, the daily water charge would be around £1.60 for the demonstrator's cooling

Future impact

According to the demonstration performance, the cost savings of using the dew point cooling would be expected to be around £47,800/year which includes an energy bill reduction of £48,400/year and water usage cost of £600/year. The initial cost of the 100 kW dew point cooling system for future roll out is around £200k, which leads to a payback of 4.2 years.

The global data centre market has been rapidly growing over the past 40 years, which provides an enormous data centre cooling market for the new dew point cooling technology. The electrical energy used in the data centres in the UK and EU is around 40 TWh and 150 TWh respectively, of which 30%-40% is used in the cooling systems. Within the next ten years, around 5,000 new data centres will likely be developed in the UK and European countries. Combining both new and planned data centres, the overall market size of the data centre cooling sector in the next 10 years will reach £57 m/year and £285 m/year in the UK and EU respectively.

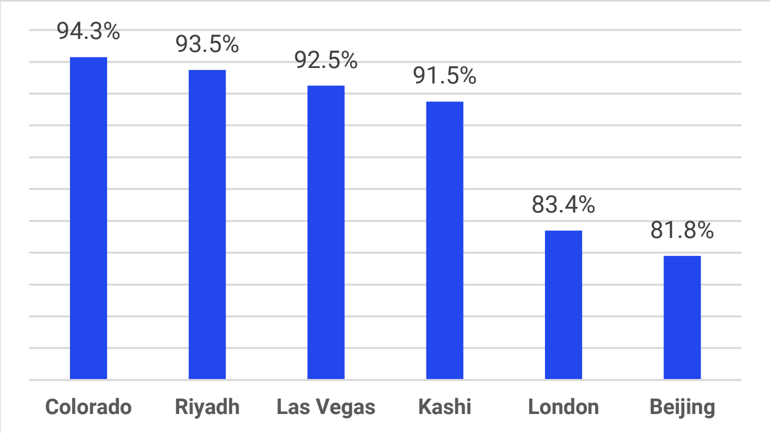

Figure 6 Energy saving potential for space cooling at various climates

Apart from data centre applications, the system can be used in other types of buildings for space cooling (railway stations, industrial and office buildings, etc.). Among the building air conditioning sector, the global evaporation cooling market was valued at USD 6.45 billion in 2020 and is expected to reach USD 8.65 billion by 2026 and grow at a CAGR of 5.1% over the forecast period (2021 - 2026), according to Mordor Intelligence. The super performance dew point air cooler will have a strong advantage as a new form of cooling technology with significantly enhanced COP which can save around 90% of energy and carbon in cooling compared with conventional vapour compression cooling (Figure 6). Furthermore, it should also give up to 50% of reduction in data centre cooling energy consumption compared to the other evaporative cooling systems.

Innovation lessons

The key learnings the partners gained through conducting this demonstration project are:

(1) Dew point cooler engineering design strategy and manufacture: The project partners managed to manufacture ten modular dew point coolers with an engineering-oriented design. Optimising the design of the heat exchanger to simplify manufacture is critical in future dew point cooling projects. The size of a dew point cooler significantly affects the installation complexity and costs, which should be carefully considered in future projects.

(2) Dew point cooler data centre installation methods and the related issues: During the project, the project partners have investigated various installation methods of the dew point coolers at the demonstration site. The process has added experience in installing the cooling units both internally and externally with installation innovations to minimise the interruptions to the site and reduce costs. In this project, the dew point coolers were installed externally to the data centre along with an air duct system to connect the data centre and the coolers.

(3) An optimised control and data presentation for the dew point cooler: The demonstration led to optimised control settings and improved data visualisation, which can be the basis for the control box of a dew point cooler.

(4) BEIS project management: The project management has been supported comprehensively by the BEIS IEEA team. It has added a significant value to the project as well as to the staff of the partners working on the project.

The success of the demonstration project has provided evidence of the high effectiveness of our innovative features (i.e., the complex heat exchanger, high water absorptive and diffusive wet-material, optimised water supply and optimised fan configurations) for improving the performance of the dew point cooler. The success of the demonstration project has provided evidence for industrial companies in the data centre and other building HVAC sectors to adopt this super performance dew point cooler to save energy and cut carbon emissions. Currently, there are around 1,000 evaporative cooling product manufacturers in operation, including world-class businesses, but there are barriers to uptake. This technology can help overcome barriers and stimulate increased evaporative cooling uptake. The UK will benefit from (1) product sale and installation, (2) fan and control system manufacturing and export, and (3) knowledge/technology transfer leading to enhanced economic/industrial competitiveness, reduced fossil fuel consumption and carbon emissions, and increased job opportunities.

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