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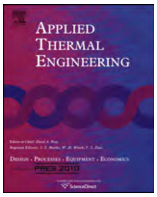

Effects of discharge recirculation in cooling towers on energy efficiency and visible plume potential of chilling plants

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ABSTRACT

Due to limited space and/or improper placement of evaporative cooling towers, discharge recirculation likely occurs in practical applications. The air recirculation may adversely affect energy efficiency of the chilling plants and increase the potential of visible plume around the towers. In this study, the amount of recirculation in a counter-flow cooling tower is evaluated by computational fluid dynamics (CFD) simulation tests under different enclosure structures and crosswind conditions. Then the effects of recirculation in cooling towers on energy performance of a chilling plant and plume potential are investigated. The evaluation is conducted on a dynamic simulation platform using the weather data in a typical meteorological year of Hong Kong. Results show that crosswind can enhance recirculation in cooling towers under lower air flow rate conditions. The recirculation ratio can reach up to 15%. Results also reveal that air recirculation in cooling towers could result in the increase of overall chilling plant energy consumption by over 1.5%. The recirculation also results in significant increase of plume occurrence frequency, particularly in spring season.

1. Introduction

Heating, ventilating and air-conditioning (HVAC) systems are the major electricity users in modern cities nowadays, accounting for almost half of the energy used in buildings and around 10–20% of total energy consumption by all end-users [1,2]. Maintaining and improving the efficiency of air-conditioning systems in buildings are essential for conservation of energy resources and protection of the environment. Water-cooled vapor-compression chillers with evaporative cooling towers have been widely used to provide cooling for central air-conditioning in commercial and industrial buildings, since they are generally more energy efficient than air-cooled chillers [3]. Cooling towers are economic and effective devices for heat rejection using direct evaporative cooling technology [4,5]. Combined heat and mass transfer occurs in the hot water evaporative cooling process in the cooling towers. The wet bulb temperature and air flow rate of the entering air are two key factors influencing the rate of evaporation and hence affecting cooling tower performance.

In common mechanical induced draft cooling towers, fans at the discharge are used to draw air through the towers. It produces relatively low entering and high exiting air velocities, reducing the possibility of discharge recirculation in which the exiting air flows back into the air intake [5]. But in practical applications, due to limited space or improper design and placement of cooling towers, discharge recirculation may occur. For instance, some cooling towers are installed in wells or located adjacent to walls of their served buildings due to limited space. It will cause unfavorable flow interaction nearby the cooling towers and result in the recirculation of the hot and moist exhaust air. In addition, in order to pursue the esthetics of a building, decorative enclosures are likely designed and utilized to surround evaporative cooling towers. It can cause discharge recirculation, especially when the enclosures are higher than cooling towers. Furthermore, when a number of cooling towers are installed centrally, such as on the top of a building, the discharge from upstream cooling towers may be drawn into the intakes of downstream cooling towers. It can aggravate the recirculation in this situation [6].

There were some experimental and numerical research works [7–10] conducted to investigate the discharge recirculation in large-scale cooling towers. Moore et al. [7] and Gu et al. [8] reported that the wind perpendicular to the tower's major axis was significantly correlated with the recirculation. In addition, field measurements indicated that recirculation increased as the wind speed increased until a maximum value of recirculation occurred, and then further increase of the wind speed resulted in a decrease in the recirculation. Becker et al. [9] adopted a numerical model to study the plume recirculation in a cooling tower. It was found that the intake velocity, discharge velocity, crosswind speed and wind direction, etc. had significant influences on the amount of recirculation. The modeling results showed that in a 4 m/s wind speed

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