PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
The University of Texas at Arlington

DESIGN, OPERATION AND MAINTENANCE OF DIRECT AND INDIRECT EVAPORATIVE COOLING SYSTEMS IN DATA CENTER THERMAL MANAGEMENT

By

ASHWIN SIDDARTH

Dissertation Advisor: Dr. Dereje Agonafer
1:00 PM, Wednesday, July 28th, 2021

[Teams]

Evaporative cooling is an alternative data center cooling solution that presents significant energy cost savings in acquisition and operation when compared to conventional air conditioning and mechanical refrigeration systems. This research focuses on developing a deeper understanding in implementing, operating, and maintaining evaporative cooling systems integrated with air-side economization to realize the energy savings potential in data center cooling. An air handling unit (AHU) serves as a building block of any cooling equipment and houses the primary heat exchanger, air filters, air movers, a duct and damper system along with necessary electrical and control systems. The proposed approach systematically develops a comprehensive body of knowledge in evaporative cooling applicable to data center cooling. The territorial and climatic limitations of each evaporative cooling system integrated with air- and water-side economization for favorable ambient conditions is analyzed based on a psychrometric-based and data-driven modeling approach coupled with typical meteorological year data for various climate zones.

For direct evaporation cooling, three types of wet cooling media pads are experimentally characterized for the saturation effectiveness and system pressure drops. Analysis of the media pads based on experimentally validated CFD models establishes the criteria for media pad selection and sizing. The impact of calcium scaling due to continuous evaporation in the media pad is studied by designing and conducting an accelerated degradation test that determines the health monitoring parameter of the media pad and the maintenance interventions in the field. To achieve incremental humidification, a vertically split and staged media pad with discrete pumps for each stage is proposed to maximize water savings. The effectiveness is demonstrated by conducting characterization testing on the air flow bench under controlled inlet air conditions. The mixing chamber in the AHU is comprehensively studied to eliminate the thermal stratification issue which can exacerbate the hot spots in the data center.

For indirect evaporative cooling, a separate AHU is designed, fabricated, and commissioned in Dallas, TX. The heat exchanger is an epoxy-coated Aluminum plate heat exchanger in the cross-flow configuration with a water distribution system comprising spray nozzles/sprinklers. In these systems, the data center and outdoor air streams are segregated by the structure of the heat exchanger that still must affect efficient transfer of energy from the IT equipment exhaust into the outdoor air stream. In many cases the heat exchanger is wetted on the outdoor side to increase the range of ambient conditions (via adiabatic cooling) for which full free cooling can be realized. This addition of water not only changes the properties of the external air stream, but also the effectiveness of the heat exchanger. This research investigates how the effectiveness of an air-to-air heat exchanger changes as it is wetted, additionally identifying the off-exchanger conditions from a temperature perspective with the aim of producing a characteristic relationship that could be implemented by a simulation tool to give a reasonable approximation of heat transfer performance and used for analysis of the consequence of recirculated air affecting neighboring units. Two different types of water distributors are tested and at various heights from the top surface of the heat exchanger. A water collection grid is designed to map how well the spray system effectively distributes water within the heat exchanger passages. Heat exchanger performance is tested for fully wet, partially wet and flooded wetting configurations. Finally, large-scale data center simulation models are constructed to analyze the facility level integration and airflow management of evaporative cooled AHUs.