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Experimental investigations of thermal managements solutions in data centers buildings for different arrangements of cold aisles containments

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ABSTRACT

Cold aisles containments are used in data centers buildings to improve the thermal managements of the IT servers. In the present study, an experimental investigation of air flow and thermal management of data center buildings is conducted for different arrangements of cold aisles containments. A scaled physical model simulating real data centers is designed using scale modeling theory and constructed for the sake of the present experimental work. The data center scaled model accommodate a row of three racks; each rack included four servers for testing purposes. Three arrangements of cold aisles are tested: (i) free open cold aisle, (ii) semi-enclosed cold aisles where the aisles are enclosed from the sides, and (iii) full enclosed cold aisles, where the aisles are enclosed from sides and top. Front and rear racks temperatures profile, servers temperatures and performance measuring parameters Supply/Return Heat Index (SHI/RHI) are used to evaluate the thermal management/performance of the data centers racks. Experiments were conducted at different racks power densities. The results showed that (i) increasing data centers power density and supplied air flow rates improves SHI but increases servers temperature, (ii) using semi-enclosed cold aisles relatively improve the thermal performance of the data centers, (iii) using full enclosed cold aisles dramatically improve the thermal performance of the data center servers, and (vi) the percentage of enhancement in data centers performance due to using cold aisle containments dramatically increases with increasing the power density.

1. Introduction

Data center is a room that accommodate an array of racks. Each rack includes a group of servers, typically four servers, for data storage and data processing. Data centers are used in banks, telecommunications and mobile phones companies, market transactions, universities and others special and private applications. Recent studies showed that data center consumes a huge amount of the total power consumption of modern cities. It was reported that data centers consumed 61 billion kWh or about 1.5% of U.S. total electricity consumption in 2006 [1]. A large portion of this consumed energy (almost 50%) is necessary for cooling of servers to maintain their temperature within the allowable limits [2]. The properly manage data center cooling process would reduce this portion of energy. Consequently, a much more detailed understanding of air flow and temperature distributions for proper thermal management in data centers is a vital issue to operate the data centers within the required specifications while avoiding excessive use of cooling. Layout and features of all data centers are similar; most they use raised-floor configuration. Fig. 1 shows a typical schematic view of open aisle data centers [3]. The racks are arranged in a hot-/cold-aisle configuration with standard alignment like that shown in Table 1 [4]. The cold aisle contains perforated tiles that supply cold air to the inlets of the server racks from the under-floor plenum. The hot air leaving the racks is extracted by the Computer Room Air Conditioning (CRAC) unit to re-cool and supplies it as cold air to data center plenum to complete the cycle. This concept of energy management for data centers prevents the unwanted mixing of the hot air expelled from the servers with the cooling air coming from the perforated tiles. However, hot air recirculation and cold air bypass must be considered in design and operation stage in order to prevent a drop in the servers cooling efficiency.

Efficient thermal management of data centers can be maintained by using proper air distribution in the room that would reduce or prevent the hot air recirculation and/or the cold air bypass. For this purpose, physical separation (aisle partition) of hot and cold aisles has been suggested [5]. Containment of air throughout the data center is an important thermal management and energy saving strategies that results in the data center optimization especially in high power density data center. Most of the modern energy efficient data centers use some kind of

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Nomenclature

Q	heat dissipation (W)
Cp	specific heat of air at constant pressure, (J/kg k)
$\dot{m}$	mass flow rate (kg/s)
T	temperature (°C)
T_{ref}	reference temperature (°C)
CRAC	Computer Room Air Conditioning
RHI	return heat index
SHI	supply heat index
U	velocity (m/s)
L	length (m)
ν	kinematic viscosity (m^2 /s)
α	length scale$=L_m/L_R$
τ	time scale
Re	Reynolds number
Ar	Archimedes number
Pr	Prandtl number

Superscripts

r	rack
c	CRAC

Subscripts

in	inlet
out	outlet
m	for model
R	for real data center
i,j	Cartesian direction

containment system [6–9]. Generally, the major benefit of aisle partition and containment is the mitigation of server air inlet temperatures due to the minimum mixing of cold air with hot air. Gondipalli et al. [6] conducted a computational study on the effect of using cold aisle compartments. The results showed that a 15–40% reduction in rack inlet temperature can be obtained by using cold aisle compartments for the same room layout and cold air supply. In this regard, Vikneshan et al. [7] reported that, the fully provisioned contained aisle is preferred in case of no geometrical or cost limitations otherwise the partial containment is a good accepted option. Vaibhav et al. [8] showed that, the containment of the cold aisle tends to significantly improve the temperature uniformity in the cold aisle, as well as at the server inlets temperature. Saurabh et al. [9] found that, a containment system reduces the overall cooling energy cost by preventing or reducing the mixing of cold and hot air streams.

Data center thermal management performance and effectiveness is normally evaluated in terms of performance dimensionless metrics; Supply Heat Index (SHI) and the Return Heat Index (RHI) [10,11]. Using these indices, heat transfer and thermal management inside the data centers can be understood and evaluated. Cho et al. [12] studied air distribution inside high compute density (Internet) data centers and reported that the air velocity is not an important factor for the data center designers where human thermal comfort is not a significant factor. Shrivastava et al. [13] reported that supply the cold air from raised floor and extract the return air from ceiling is the most efficient air distribution system. On the other hand, the ceiling supply with under floor return leads

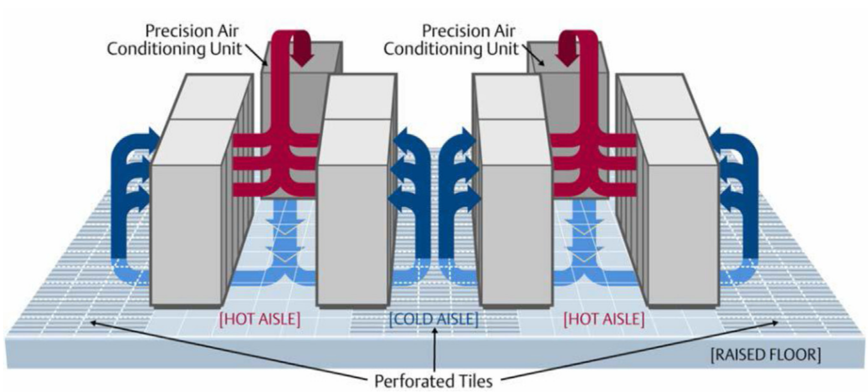

Fig. 1. Typical open aisle data center [3].