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Experimental investigations of air conditioning solutions in high power density data centers using a scaled physical model

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ABSTRACT

The widespread use of data centers, the dramatical increase of the data center power density and the need for improving cooling system efficiency to maintain reliable operation temperature and save cooling energy make the study of data center thermal management an urgent issue. In the current paper, three different configurations for thermal management solution of high power density data centers are investigated, compared and evaluated. A scaled physical model data center has been designed and constructed for the sake of the study using the theory of scale modeling of air flow experiments. The results showed that (i) by using aisle partition and aisle containment the rack inlet temperature can be reduced by 3–13% and 13–15.5% for aisle partition and aisle containment configurations, respectively; (ii) the intake air temperature reduction increases with increasing power density; and (iii) using aisle partitions and aisle containment with raised floor improves the data center cooling performance.

Études expérimentales des solutions de conditionnement d'air dans des centres de données à forte densité électrique en utilisant une maquette

Mots clés : Centre de données ; Conditionnement d'air ; Modélisation physique ; Gestion thermique ; Partition d'allées ; Confinement d'allées ; Frigorigène ; Monocouche auto-assemblée ; Mouillage

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Nomenclature

Q	heat dissipation [W]
Cp	specific heat of air at constant pressure [$J \cdot kg^{-1} \cdot k^{-1}$]
$\dot{m}$	mass flow rate [$kg \cdot s^{-1}$]
T	temperature [°C]
T_{ref}	reference temperature [°C]
CRAC	computer room air conditioning
RHI	return heat index
SHI	supply heat index
U	velocity [$m \cdot s^{-1}$]
L	length [m]
ν	kinematic viscosity [$m^2 \cdot s^{-1}$]
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

1. Introduction

Data centers are widely used in different industrial applications where large/high-speed data processing is necessary, such as telecommunications, data storage and processing in banks, market transactions and other 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 (EPA, 2007). A large portion of this consumed energy (almost 50%) is necessary for cooling of servers to maintain their temperature within the allowable limits (ASHRAE, 2008). The properly managed 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; mostly they use raised-floor configuration. Fig. 1 shows a typical schematic view of open aisle data centers (Patankar, 2010). The racks are arranged in a hot-/cold-aisle configuration with standard alignment like that shown in Table 1 (ASHRAE, 2004). The cold aisle contains perforated tiles that supply cold air to the inlets of the server racks from the underfloor 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

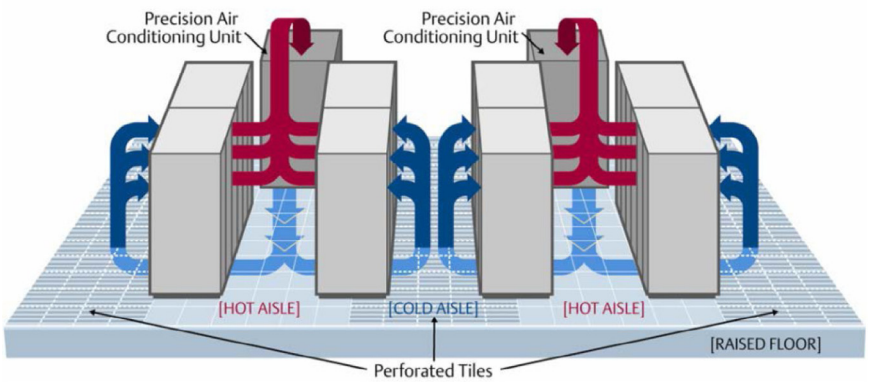

Fig. 1 – Typical open aisle data center (Patankar, 2010).

Table 1 – Aisle pitch allocation and rack arrangements with separation (ASHRAE, 2004).

	Tile size	Aisle pitch	Cold-aisle size	Hot-aisle size
U.S.	2 ft (610 mm)	14 ft (4267 mm)	4 ft (1220 mm)	3 ft (914 mm)
Global	600 mm (23.6 in)	4200 mm (13.78 ft)	1200 mm (3.94 ft)	914 mm (3 ft)
Seven-title aisle pitch, equipment aligned on cold aisle