Cooling Systems for IT Environment Heat Removal
in (Internet) Data Centers

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Abstract

Internet Data Center (IDC) heat removal is one of the most essential yet least understood of all critical IT environment processes. The cooling of data centers has emerged as a significant challenge as the density of computing equipment increases. In this research, environmental aspects of energy consumption and load-profile were studied through the survey of domestic data centers that need all year round cooling load. The energy-using patterns of cooling system combined with real power density are compared and energy saving effects of data center is reviewed. All cooling systems use CRAC or CRAH units of some kind, which come in various capacities and remove the heat from the room. There are five heat removal methods and two common physical equipment arrangements that can be combined to create ten basic types of cooling systems. Air supply and air return systems each have three and four different configurations that can be combined to create thirteen basic types. An understanding of the many types of cooling/air distribution systems and their attributes can be used to develop guidelines for when each type should be used, and such guidelines are provided in this study for both raised floor and hard floor applications. The design criteria of cooling and air distribution systems were analyzed using quantitative data acquired by surveying 20 multi-megawatt data centers in Korea. It provides the best configurations and design criteria for different IT environments and common practices and equipment options that may increase cooling system availability.

Keywords: (Internet) Data Center; IT environment; IT server; heat load; cooling system; air distribution system; CRAC/CRAH

1. Introduction

South Korea is one of the leading countries in information technology industry. As the computing power and heat load of IT equipments in data centers increase exponentially, the importance of cooling and air distribution systems with regard to heat removal efficiency is growing. (Cho et al., 2006) The most important components in a data center are IT servers. Therefore, correct environmental control for safe and effective operation of such equipment is required. Research currently underway in data centers are very active in the fields of information technology and electronics, and are being run on IT equipment. But there are simply not enough studies regarding the planning and mechanical systems of data centers in the architectural or mechanical engineering fields. (Cho et al., 2007) With the rapid increase in demand in recent years, data centers are being constructed in diverse functional forms and sizes. As such, top priority should be given to the selection of cooling and air distribution systems, based on consideration of each IT environment such as data center size and IT loads of the servers. The aim of this study is to classify and present air conditioning systems for IT environments that are different in terms of data center size and composition, and present optimal IT environments.

2. Methods

The purpose of this study is to provide a foundation upon which IT professionals can successfully manage the specification, installation and operation of cooling systems for IT environment. First, design conditions concerning temperature and humidity of a data center were organized, and the methods regarding data center cooling, air distribution and equipment arrangements were reviewed. Second, the IT environment in a data center was analyzed according to temperature and humidity changes. For this, a large data center with a lot of IT equipment was chosen, and its temperature, humidity and energy consumption measured. Third, the air conditioning system aspects of the design criteria

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were analyzed using quantitative data acquired through a survey of 20 multi-megawatt data centers. Finally, with consideration given to all conditions of diverse IT environments, an applicable and comprehensive air conditioning system design map was devised.

3. Temperature and Humidity Design Conditions

IT server produces an unusual, concentrated heat load, and at the same time is very sensitive to changes in temperature and humidity. Standard comfort air conditioning is not designed to handle the heat load concentration and heat load profile of IT server rooms, nor is it designed to provide the precise temperature and humidity set point required for these applications. Maintaining temperature and humidity design conditions is critical to the good operation of an IT server room. Design conditions should be 20-25°C and 40-55% relative humidity. As damaging as the wrong ambient conditions can be, rapid temperature swings can also have a negative effect on facility operation.

4. Basic Air-conditioning System Configurations

(1) Cooling Methods, Equipment Arrangements

Ten types of system configuration are possible for data center cooling systems; by combining five types of cooling methods for heat removal - air cooled self-contained systems, air cooled systems, glycol cooled systems, water cooled systems, and chilled water systems, with two CRAC unit mounting methods in the IT environment - floor mounted and ceiling mounted.

(2) Air Distribution Methods in Different Floor Types

Air distribution of all air conditioning systems consists of supply air and return air. That is, it is differentiated into a supply system that supplies cooled air from the CRAC unit to the IT load part, and a return system that draws the air that has flowed through the IT equipment and eliminated the load back to the CRAC unit. This air distribution system of supply air and return air has three types of basic methods, flooded supply, locally ducted supply and fully ducted supply. Of these, the locally ducted supply method is differentiated into down-flow type and up-flow type, depending on whether the structure has a hard floor or raised floor. When the internal flow methods of the equipment for a hard floor are added to the

Table 1. IT Environment Specifications (ASHRAE, 2004)

| Class | Allowable | Recommended | Dew Point |
|-------|-----------|-------------|-----------|
|       | DB (°C)   | RH (%)      | DB (°C)   | RH (%) |
| 1     | 15 to 32  | 20 to 80    | 20 to 25  | 40 to 55 | 17°C |
| 2     | 15 to 35  | 20 to 80    | 20 to 25  | 40 to 55 | 21°C |
| 3     | 5 to 35   | 8 to 80     | NA        | NA      | 28°C |
| 4     | 5 to 40   | 8 to 80     | NA        | NA      | 28°C |
| NEBS  | 5 to 40   | 5 to 85     | 18 to 27  | Max 55  | 28°C |

Table 2. Basic Cooling System Configurations (Tony Evans, 2004)

Table 3. Different Types of Air Distribution Systems (Neil Rasmussen, 2003a)
system combined with four types of supply systems and three types of return systems, thirteen system combinations in total are possible. Since the main goal of a data center air distribution system is to prevent IT equipment from overheating, it is important to ensure that there is no mixing of the air going into and out of the air inlet and outlet mounted on the equipment itself. The purpose of such planning is identical to the differentiation of cold/hot aisles and can increase the efficiency and cooling capacity of a CRAC unit.

5. Analysis of IT Environment in a Data Center
(1) Temperature and Humidity Distribution Analysis
To analyze IT load variations of data center that are due to the influence of external environment factors such as outdoor air temperature, actual temperatures of high-density facility areas inside the IT server room were measured, and the heat load and air temperature patterns in relation to the outdoor air temperature were analyzed. Temperature and humidity was measured every five minutes by the data logger (Agilent/34970A). Fig. 2. shows the position of the measurement sensors and the equipment.

The result of measuring the temperatures of high-density facility areas in the IT server room shows that they vary from a minimum of 18°C to a maximum of 23°C. When they were compared with the outdoor air temperature for the same time periods, the interior temperature remained constant regardless of the outdoor air temperature changes. Also, there was almost no change in the volume of energy consumption in operating the CRAC unit for the same time period (next chapter). This was taken to mean that the outdoor air temperature did not significantly influence interior load changes because the IT server room does not directly face the exterior wall and most of the heat gain comes from the facility.

(2) Temperature at the Front/Back Side of the IT Server
The temperatures at the front and backside of the IT server were measured and the air temperature was observed after the heat inside the actual server was eliminated. With most IT servers, about 50% of the total equipment heat density occurs in the CPU. The heat is eliminated using fans installed in the IT server to remove heat from the chipset by the conditioned air In order to measure actual temperatures at the front and backside of the IT server, a specific server was selected and four points at the upper and lower parts of the front and backside were measured every five minutes. The results from measuring the front and backside of IT server show that the temperature at the lower part of the front side remains constant, as it is close to the supply air diffuser, while the temperature at the upper part fluctuates greatly because the heat from the equipment at the lower part mixes with the inside heat. As far as the backside is concerned, because the air...
contains the heat that was eliminated from inside the IT server, the area shows a high temperature distribution. The upper part of the backside maintained an average temperature of over 35°C. The temperature surrounding the facilities increases due to the heat from inside the server, but as the air current contains the heat that has been eliminated from the CPU, it is natural that the temperature should rise. The average front and backside temperatures were 22.6°C and 32.0°C respectively, which is about \(\Delta T = 9.4°C\) temperature difference. It is judged that there will be differences according to the IT server capacity and the level of rack configuration.

(3) Energy Consumption

In order to discover the data center's energy consumption tendencies, data for daily and weekly electricity usage were collected. Also, the outdoor air temperature for the same time periods and the average and maximum daily temperatures were examined. As mentioned above, the heat load of data center is not significantly influenced by changes in the outdoor air temperature. The IT server, which causes most of the interior heat, is responsible for a consistent cooling load all year round even though there are small differences according to its rate of operation. The daily and weekly electricity consumption of data center remains almost within its design conditions, and does not show any particular tendency to change according to other factors such as outdoor air temperature.

6. Air-conditioning System Case Analysis

To select optimal cooling systems of data center (air-conditioning system and central plant), actual cases of data center application were analyzed. Large data centers, including Internet data centers and financial institutions data centers, were selected and analyzed. The surveyed data centers’ floor space is 465 m² or greater and qualified as large data centers as previously defined. About 80% had the raised floor environment. In addition, the height of the raised floor for the majority, approximately 81%, of those confirmed was 600 mm or greater. The average IT loads of about 685 W/m² was smaller than the latest trend. Mixing with old-model IT servers appears to be the reason for this. As stated earlier, data center cooling systems can come in ten-system combination types based on five cooling methods and the two CRAC unit installment methods (floor mounted and ceiling mounted). However, the surveyed data centers were of the large data center group, and since using small capacity ceiling mounted CRAC units was impossible, the floor-mounted types were used.

Chilled water systems (CWF) made up a majority, approximately 65%, of the central plant systems. This appears to be the case because with these systems, although the relative facility cost increases, stability in cool water supply can be secured. Next in line were direct expansion air-cooled systems (DXF), which consisted of a high usage rate of about 15%. For efficient quantity-related control, these systems generally require as many air-cooled condensers as CRAC units and therefore increase equipment installation space. But because of their easy operation, these systems are used extensively. Next, in descending order, were glycol-cooled systems (GCF) and water-cooled systems (WCF).

Depending on the IT environment, there were
### Table 4. Analysis of 20 Multi-megawatt Data Centers

| Building Description | SK C&C Data Center | LG CNS Data Center | Samsung SDS Data Center (a) | Samsung SDS Data Center (b) | Hyundai IT Data Center |
|----------------------|--------------------|--------------------|----------------------------|-----------------------------|------------------------|

#### Building View

| Location | Completion | Built-up Area | Cooling System | Air distribution | Conditions | Heat Density | Floor Type | Building Description |
|----------|------------|---------------|----------------|------------------|------------|--------------|------------|----------------------|
| Yuseong, Daejeon | 2001 | 14,600 m² (4,500 m²) | DXF (1-1) | RLSCR | DB21°C / RH50% | Raised Floor (600 m²) | GNG Internet Data Center |
| Gyeong, Incheon | 1992 | 14,400 m² (4,800 m²) | DXF / CWF | RLSLR | DB19°C / RH50% | Raised Floor (600 m²) | KFTC Data Center |
| Gwacheon | 1992 | 18,000 m² (5,950 m²) | DXF / CWF | RLSLR / HCRSC | DB21°C / RH50% | Raised Floor (600 m²) | KT Internet Data Center (a) |
| Gumi | 1996 | 19,500 m² (5,100 m²) | CWF | RLSLR | DB21°C / RH50% | Raised Floor (600 m²) | KT Internet Data Center (b) |
| Yongin | 2005 Remodeling | 25,700 m² (11,100 m²) | CWF | RLSLR | DB21°C / RH50% | Raised Floor (600 m²) | Supreme Court Data Center |
| Bundang, Seongnam | 2000 | 14,000 m² | DXF (1-1) | RLSLR | DB22°C / RH45% | 580 W/m² | IBM Data Center (a) |
| Bundang, Seongnam | 2007 | 22,400 m² | CWF | RLSLR | DB22°C / RH45% | 600 W/m² | IBM Data Center (b) |
| Bundang, Seongnam | 2001 | 31,600 m² (13,500 m²) | CWF | RLSLR | DB22°C / RH45% | 1,380 W/m² | Securities Depository Data Center |
| Yangcheon, Seoul | 2008 | 64,700 m² (22,500 m²) | CWF | RLSLR | DB22°C / RH45% | 500 W/m² | NCIA Data Center |
| Bundang, Seongnam | 2008 | 22,200 m² (2,110 m²) | CWF | RLSLR | DB22°C / RH45% | 500 W/m² | NCIA Data Center II |
| Songdo, Incheon | Design Phase | 13,200 m² (6,600 m²) | GCF | RLSLR | DB22°C / RH45% | 1,080 W/m² | Shinhan Bank Data Center (a) |
| Gangnam, Seoul | 1999 | 83,100 m² (1,200 m²) | CWF | HCRSC | DB22°C / RH45% | 530 W/m² | Kookmin Bank Data Center |
| Ilsan, Goyang | 1998 | 22,500 m² (1,200 m²) | CWF | RLSLR | DB22°C / RH45% | 530 W/m² | Industrial Bank Data Center |
| Yuseong, Daejeon | 2005 | 31,700 m² (10,100 m²) | CWF | RLSLR | DB22°C / RH45% | 740 W/m² | Shinhan Bank Data Center (b) |
| Seogu, Gwangju | 2007 | 33,200 m² (10,000 m²) | CWF | RLSLR | DB22°C / RH45% | 1,000 W/m² | SC First Bank Data Center |

#### Building View

| Location | Completion | Built-up Area | Cooling System | Air distribution | Conditions | Heat Density | Floor Type | Building Description |
|----------|------------|---------------|----------------|------------------|------------|--------------|------------|----------------------|
| Songdo, Incheon | Design Phase | 13,200 m² (6,600 m²) | GCF | RLSLR | DB22°C / RH45% | 1,080 W/m² | Raised Floor (900 m²) | Shinhan Bank Data Center (a) |
| Gangnam, Seoul | 1999 | 83,100 m² (1,200 m²) | GCF | HCSC | DB22°C / RH45% | 530 W/m² | Hard Floor | Kookmin Bank Data Center |
| Ilsan, Goyang | 1998 | 22,500 m² (1,200 m²) | GCF | RLSLR | DB22°C / RH45% | 530 W/m² | Hard Floor | Industrial Bank Data Center |
| Yuseong, Daejeon | 2005 | 31,700 m² (10,100 m²) | GCF | RLSLR | DB22°C / RH45% | 740 W/m² | Raised Floor | Shinhan Bank Data Center (b) |
| Seogu, Gwangju | 2007 | 33,200 m² (10,000 m²) | GCF | RLSLR | DB22°C / RH45% | 1,000 W/m² | Raised Floor (600 m²) | SC First Bank Data Center |

#### Building View

| Location | Completion | Built-up Area | Cooling System | Air distribution | Conditions | Heat Density | Floor Type | Building Description |
|----------|------------|---------------|----------------|------------------|------------|--------------|------------|----------------------|
| Gangnam, Seoul | 1996 | 23,700 m² (6,200 m²) | CWF | RLSLR | DB20°C / RH50% | 500 W/m² | Raised Floor (500 m²) | Gangnam, Seoul Data Center |
| Gangseo, Seoul | 2006 Remodeling | 14,000 m² (3,900 m²) | WCF | RLSLR | DB20°C / RH50% | 640 W/m² | Raised Floor (600 m²) | Gangseo, Seoul Data Center |
| Sui, Yongin | 2006 Remodeling | 26,300 m² (1,600 m²) | WCF | RLSLR | DB20°C / RH50% | 520 W/m² | Raised Floor (400 m²) | Sui, Yongin Data Center |
| Ilsan, Goyang | 1999 | 24,500 m² (4,000 m²) | CWF | RLSLR | DB20°C / RH50% | 700 W/m² | Hard Floor | Ilsan, Goyang Data Center |
| Songpa, Seoul | 1985 | 21,300 m² (2,700 m²) | CWF | RLSLR | DB20°C / RH50% | 700 W/m² | Hard Floor | Songpa, Seoul Data Center |

**Remark**

- ■ Power density according to design condition
- □ Power density according to actual equipment capacity
significant differences in data center air distribution systems. In raised floor environments, which comprised the substantial portion of the data centers surveyed, the raised floor locally ducted supply and locally ducted return (RLSLR) system made up about 52%. The raised floor locally ducted supply and CRAC flooded return (RLSCR) system made up about 25%, mostly in cases where the ceiling was unfinished or the power and network cables for the IT servers were planned to be run across the upper part of the room. In hard floor structures where the CRAC unit is often installed in the CRAC equipment room, the hard floor CRAC flooded supply and CRAC flooded return (HCSCR) system, exposed to the room interior, was found to be 18%, while hard floor locally ducted supply and locally ducted return (HLSLR) system was about 5%.

7. Design Guide for Data Center Cooling System

(1) Size-variables and Floor Type of IT Environments

Depending on floor space, the number of servers installed, and the total amount of power used, IT environments can be classified broadly into five types: wiring closets, computer rooms, and small, medium, and large data centers.

| Area                | IT Environment                                      |
|---------------------|----------------------------------------------------|
| Wiring Closets       | 1-3 rack enclosure / equivalent using 1-18 kW of electricity |
| Computer Rooms      | 1-5 rack enclosure / equivalent using 3-30 kW of electricity |
| Small Data Centers  | < 93 m$^2$ 5-20 rack enclosure / equivalent using 7-100 kW of electricity |
| Medium Data Centers | 93 m$^2$ ~ 465 m$^2$ 20-100 rack enclosure / equivalent using 28-500 kW of electricity |
| Large Data Centers  | > 465 m$^2$ >100 rack enclosure / equivalent using > 200 kW of electricity |

Because, for structural reasons, many IT server models have the heat removal ventilation opening at the lower part of body, and power distribution and telecommunication infrastructure are placed under the floor, the raised floor has been the dominant structure for data centers. However, since it cannot be applied to all data centers of various sizes, a significant number of multi-megawatt data centers do not use raised floor environment. There are drawbacks in using a raised floor, including specialty engineering, cost, design time, earthquake susceptibility, safety hazard, security reliability and other problems. Accordingly, for newest data centers, raised floor environment and hard floor environment are equally considered for creating an appropriate IT environment.

(2) Design Roadmap of Suitable Cooling and Air Distribution Systems for IT Environments

The applicability of a cooling system in relation to the IT environment is mainly determined by the equipment capacity. For small size IT environments, small cooling capacity CRAC unit installation is possible because the IT load is small. A ceiling mounted type CRAC unit, because of its small cooling capacity, can be used for small data centers; in contrast, because of its large capacity, the installation of a floor mounted type is limited.

Table 5. Summary of Surveyed Data Center Application

| Average Condition       | DB21.5°C / RH47%       |
|-------------------------|------------------------|
| Average Heat Density    | 685 W/m$^2$           |
| Floor Type              | Raised Floor (80%)     |
| Height of Raised Floor  | Over 600mm (81%)      |
| Majority Cooling System | © Chilled Water System |
| Majority Air Distribution System | © Raised Floor Locally Ducted Supply and Return System |

In particular, although the raised floor method has been dominant in data centers, the hard floor method is being seriously considered for safety in the wake of the 9/11 attacks in the US. Moreover, the fear of not being able to adequately cool potential hot spots within a data center using conventional raised floor designs has lead to extensive over sizing of the cooling plant and air distribution system, causing an extensive increase in construction cost. Ductwork for the supply air and cooling air provides the means to address high heat density areas, while avoiding the costs of oversized cooling system.
As for central plant systems, the chilled water systems and water-cooled systems that use chillers and cooling towers are used mostly in medium and large data centers because of equipment capacity. However, even in a small IT environment, if the central plant system for the office area is shared, then using a chilled water system is possible.

The cooling and air distribution systems applicable to diverse IT environments have been classified earlier in this paper. Selecting a data center air conditioning system requires comprehensive consideration from the perspectives of safety, efficiency and reliability.

Table 7. Design Roadmap for Data Center Cooling

| Cooling System Configurations | Air Distribution Systems |
|------------------------------|--------------------------|
|                              | CRAC Flooded | Locally Ducted | Fully Ducted | Supply |
|------------------------------|--------------|----------------|--------------|--------|
|                              | CRAC Flooded | Locally Ducted | Fully Ducted | Raised Floor |
|                              | CRAC Flooded | Locally Ducted | Fully Ducted | Hard Floor |

System, Summary & Cooling Approach

1. Dropped ceiling for condenser air duct exists. Portable systems are for less than 12 kW of equipment or hot spots for emergency use.
2. Dropped ceiling for condenser air duct exists. Ceiling mounted systems are OK for 6–30 kW loads.
3. Building has roof access and available space for Chilled. Large systems are OK for loads greater than 25 kW.
4. Building has roof access and 3m floor to structural ceiling height. Ceiling mounted systems are OK for 6–30 kW loads.
5. Building has roof access but data center is far away. Large systems are OK for loads greater than 25 kW. Free cooling in cold winter.
6. Building has roof access and 3m floor to structural ceiling height. Long distance to outdoors.
7. Condenser water system has more available capacity or lower usage cost than chilled water.
8. Not commonly used.
9. Data center has mission critical chilled water supply and reliable chilled water supply without setbacks.
10. Not commonly used.

Wiring Closets

1. Under 3 kW per rack average, with very high ceilings or under 100 kW total power
2. High average per rack power or over 100 kW total power / Cools rack to 5 kW and to 8 kW
3. Alternate high density solution for mainframe environment / Cools rack to 15 kW
4. Under 10 rack or 40 kW / Simple installation / Low cost / Cools rack to 3 kW and to 15 kW
5. Under 100 rack or 150 kW with only occasional high density racks / Low cost / Cools rack to 3 kW and to 8 kW
6. Not recommended / Difficult to prevent air mixing
7. Part of a multi-zone larger room or with high density racks / Cools rack to 5 kW and to 8 kW
8. Takes up significant floor space. Typical system size much larger than wiring closet requirements. (Over sizing)
9. Some hi-rise buildings. No possible location for outdoor condensers, cooling source is chilled water.

Computer Rooms

1. Condenser water is not usually routed far from mechanical room. (Over sizing)
2. Some hi-rise buildings. No possible location for outdoor condensers, cooling source is chilled water.

Small Data Centers

1. Condenser water is not usually routed far from mechanical room. (Over sizing)
2. Some hi-rise buildings. No possible location for outdoor condensers, cooling source is chilled water.

Medium Data Centers

1. Insufficient capacity per CRAC unit (Under sizing)
2. Usually, large data centers have dedicated chilled water systems. Use if no chilled water system exists or capacity is not available.

Large Data Centers

1. Insufficient capacity per CRAC unit (Under sizing)
2. Usually, large data centers have dedicated chilled water systems. Use if no chilled water system exists or capacity is not available.

Remark

Stands for system’s identity according to diverse cooling and air distribution systems for IT environment.
regarding construction and costs in connection with the building system and the IT environment comprising the operating condition, power density, installation location, size of the IT servers and other factors. With consideration given to all the conditions of the diverse IT environments that have been examined in previous studies, an applicable and comprehensive air-conditioning system design map has been devised.

8. Conclusion

It is difficult to study the character of energy consumption and air-conditioning systems of IT environments because data centers are closed to the public for security reasons. This study is worthwhile simply because it surveyed the cooling systems of large data centers.

To help plan cooling and air distribution systems for rational IT environment control, this study analyzed diverse IT environments, taking into consideration IT equipment capacities and configurations, and proposed air conditioning system alternatives suitable for each environment. The results are summarized as follows:

(1) Cooling systems for data center are primarily differentiated in the way they physically reside in the IT environment and in the way they collect and transport to the outside atmosphere.

(2) Based on five types of basic heat removal methods and two common physical equipment arrangements, cooling systems can come in a total of ten system combinations.

(3) Air distribution systems come in a total of 13 system combinations, based on 3-4 method types each for supply and return systems and hard floor or raised floor environments.

(4) The result of analyzing the heat load pattern and energy consumption of case study data center through measurements of its environment and investigation of its current operating conditions show that the IT server, which causes most of the interior sensible heat, is responsible for a consistent cooling load all year round even though there are small differences according to its rate of operation. Also, because the IT server causes most of the heat density, it was analyzed that changes in the outdoor air temperature were not a significant factor in the heat load changes.

(5) Results from the survey of large data centers in Korea and abroad showed that the majority of raised floor environments had 600 mm height or greater, and the average IT heat load was around 660W/m². In addition, chilled water systems (® CWF) and raised floor locally ducted supply locally ducted return (® RLSLR) are mostly used as cooling and air distribution systems.

(6) Each of the ten cooling systems and thirteen air distribution systems has application advantages and disadvantages in diverse IT environments. Therefore, selecting and installing a cooling system requires comprehensive consideration from the perspectives of safety, efficiency and reliability, regarding construction and costs in connection with building systems and the IT environment comprising the operating condition, power density, installation location, and size of IT servers, and other factors.

Based on the heat load pattern and energy consumption figures derived in this paper, future research needs to expand the analysis to other equipment systems, select a planning guideline and an optimal system for future data centers, and present plans for reducing energy consumption.

The scope of this study was to provide air conditioning system alternatives suitable for diverse IT environments, based on case studies of system universality, equipment configuration, and installation possibilities, together with the technical data of system equipment. This in itself has value as a guideline for air conditioning system selection in the early stage of planning a data center. Subsequently, however, a follow up research that can provide specific information based on quantitative analysis of each alternative system is needed.

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