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Research Paper

Application of separated heat pipe system in data center cooling

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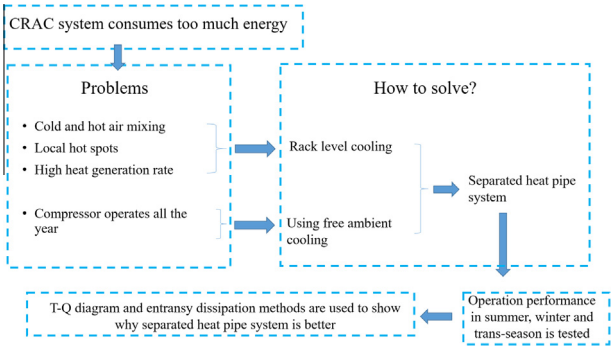
HIGHLIGHTS

- Separated heat pipe system is used in data center cooling.
- Operation performance in summer, winter and trans-season is tested.
- Heat pipe system and traditional CRAC system are compared.
- T-Q diagram and entransy dissipation methods are used.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper mainly studies the application of separated heat pipe system on data center cooling. Separated heat pipe system mainly consists of four parts: evaporator, condenser, vapor pipe and liquid pipe. Compared with traditional computer room air conditioning (CRAC) system, which is a kind of room level cooling, heat pipe cooling system is rack level cooling. There are mainly three advantages for separated heat pipe system, firstly, air flow organization is better for there is nearly no hot and cold air mixing, secondly, such system can use cold ambient air as heat sink in winter, thirdly, as the evaporator is placed directly inside the rack, heat generated from IT equipment will be soon absorbed by heat pipe system, thus there is nearly no local hot spots inside the rack. To describe the working condition of the system, there are mainly three parts in this paper. Firstly, operation performance in summer, winter and trans-season is tested. Secondly, as the system can use free cold ambient air to produce chilled water, the time of using free cold ambient air is tested. Finally, T-Q diagram is used to compare the heat transfer process in heat pipe system and traditional CRAC system. The results show that, IT equipment can work in a safe and reliable environment. Besides, the heat sink temperature in heat pipe system is much higher than CRAC system and there is nearly no cold and hot air mixing in heat pipe system. In summary, heat pipe system can save more electrical energy than CRAC system.

1. Introduction

As an important place for information storage and calculation, data center has grown rapidly all over the world. Data center mainly contains two parts: IT equipment and cooling system. As is known to all: IT equipment consumes too much electrical energy during calculating, and such energy finally turns to heat and dissipates to the computer room. The heat needs to be immediately dissipated, otherwise, the temperature of the room may rise up rapidly, which will threaten the operation safety of the data center. Traditional data center uses CRAC system as the cooling system, as

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Nomenclature

CRAC	computer room air condition
IT	information technology
PUE	power usage efficiency
T-Q diagram	temperature and heat transfer rate diagram
UPS	uninterruptable power system
PDU	power distribution unit
CPU	central processing unit
C_p	constant pressure specific heat
C_v	constant volume specific heat
CWHE	cold air-water heat exchanger
ΔT	temperature difference (°C)
Q	heat transfer capacity (kW)
Q_1	the total cooling power by chilled water (kW)
Q_2	the total heat generation power (kW)
Q_f	heat transfer capacity is the front plate (kW)
Q_b	heat transfer capacity is the back plate (kW)
$\Delta E_{n,h}$	entransy dissipation of hot air return (kW K)
$\Delta E_{n,c}$	entransy dissipation of short circuit of cold air (kW K)
T_s	rack's inlet air temperature (°C)
T_c	CRAC's outlet air temperature (°C)
T_h	rack's air outlet temperature (°C)
T_r	CRAC's inlet air temperature (°C)

can be seen in Fig. 1, cold air is produced by air conditioning. The floor is raised from the ground and cold air is supplied from the under-floor. Racks are placed face to face (in order to create the cold air stream passage) and back to back (to create hot air stream passage). Cold air is absorbed into racks from the cold air stream passage and flows through the IT equipment in the rack where the IT equipment is cooled. At last, hot air flows out of the rack and comes back to air conditioning through the hot air stream passage.

Fig. 2 shows the energy consumption composition in a traditional data center cooled by CRAC system. In the figure, PDU is the power distribution unit and UPS is the uninterruptable power system. There are mainly two parts of the energy consumption: electrical energy for IT equipment and CRAC system including chiller, distribution system like fans and water pump, humidity control system, etc. CRAC system consumes nearly 45% of the total electrical energy, which means if IT equipment consumes 1 kW electrical energy to calculation, it needs 1.5 kW electrical energy to dissipate such heat. Apparently, it is unreasonable for cooling system consuming too much energy.

Cold and hot air mixing, local hot spots and chiller operating all year round are the mainly three reasons for such huge energy consumption of cooling system.

(1) Cold and hot air mixing: Although there are cold and hot air stream passages to separate stream, there are still air mixing at different temperature levels. Such mixing can lead to irreversible lose in the heat transfer process, as a result, if there is more mixing of cold and hot air, the temperature of inlet chilled water needs to be lower, which will lead to more energy consumption.

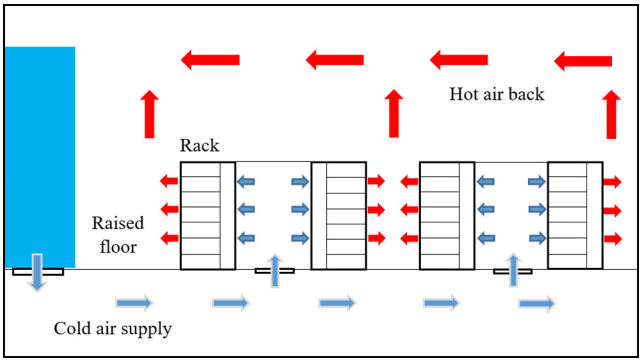

Fig. 1. The scheme of CRAC system.

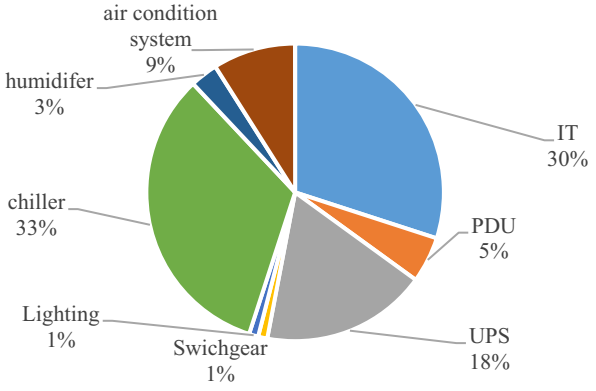

Fig. 2. Energy consumption in data center [1].

(2) Local hot spots: The heat generation rate of different IT equipment is also different. As for a rake, there is much IT equipment working at different heat generation power, thus, the heat flux at different points inside the rack are also different. However, CRAC system sends air to every rack at nearly the same mass flow rate and temperature level, as a result, there are some points called local hot spots inside the rack whose temperature is much higher. In order to solve the problem of local hot spots, the heat sink's temperature (chilled water) needs to be set extremely low, which will lead to unnecessary energy waste.

(3) Chiller operating all year round: In order to produce chilled water, chiller needs to operate all year round even in cold winter when outside ambient air is very cold even under 0 °C. In fact, we can use the cold outdoor air directly to produce chilled water instead of chiller.

There are some new methods provided for data center cooling, especially liquid cooling [2]. For example, using liquid cooling and cooling the chip directly [3], such cooling method can solve the problem of local hot spots efficiently. Using the 'direct on chip cooling' method [4–6] which cold plate is directly attached to the CPU can shorten the heat transfer path and rise the heat sink temperature. There are also some methods [7,8] use both the cold plate and air cooling. In the system, CPU and the dual inline memory module are cooled by cold plate while other IT equipment is cooled by air. However, there are some small disadvantages of liquid cooling, as the data center needs to operate in a highly security environment, water leakage may be dangerous, besides, it needs to reform the IT equipment before using the cold plate.