Energy Saving Solution for Data Centers

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OVERVIEW: Hitachi has developed the spot cooling system designed to improve data center energy efficiency, and its product range also includes ceiling suspension type units that improve space efficiency. Hitachi was also contracted by the Ministry of Internal Affairs and Communications to undertake international standardization work in which it demonstrated that the use of spot cooling systems represents best practice for data centers with a high density of installed ICT equipment. A draft containing the results of this work was submitted to the ITU as a formal Japanese proposal and subsequently adopted as a recommendation in November 2011.

INTRODUCTION

DATA center power demands are growing rapidly, driven by advances in the information society that include the faster speeds and greater capacity of information and telecommunications. It has been estimated that the volume of data passing through the Internet will expand by a factor of 190 between 2006 and 2025, during which time the amount of power consumed by information and communication technology (ICT) equipment in Japan will have grown by a factor of five. This has created an urgent need for measures that will reduce data center power consumption[(1), (2)].

Data center equipment needs to be capable of upgrading to increase capacity and must have the reliability to operate 24 hours a day, 365 days a year. Recent years have seen the emergence of problems such as an increase in power consumption by cooling systems, and also the occurrence of hot spots that are severe enough to impact equipment performance, which results from the increased amount of heat generated by the high-density packaging of ICT equipment.

This article describes the spot cooling system for data centers, and work on international standardization of data center air conditioning systems.

ISSUES FACED BY DATA CENTER AIR CONDITIONING SYSTEMS

Conventional data center air conditioning systems use floor-mounted units located at the edge of the room housing the ICT equipment or in an adjacent machine room. These are room air conditioning systems that use the underfloor ventilation method in which the air conditioners supply the ICT room with chilled air via an underfloor chamber so that this low-temperature air ventilates the server racks to cool the servers and other ICT equipment they contain (see Fig. 1).

This method requires the chilled air to circulate around a long path, including the underfloor chamber, the room housing the ICT equipment, and the ceiling space. This results in a large heat conveyance power requirement, and there is a risk of air pools or eddies forming if the balance of air flow changes, resulting in hot spots (localized increases in temperature). Also, because the air conditioners need to be installed in the same room as the ICT, or in an adjacent room, this approach limits the space available for servers and other ICT equipment. Also, if the heat density in the room is high due to factors such as high-density packaging, the underfloor chamber through which the chilled air passes needs to be made large and this in turn influences the floor-to-floor height of the building.

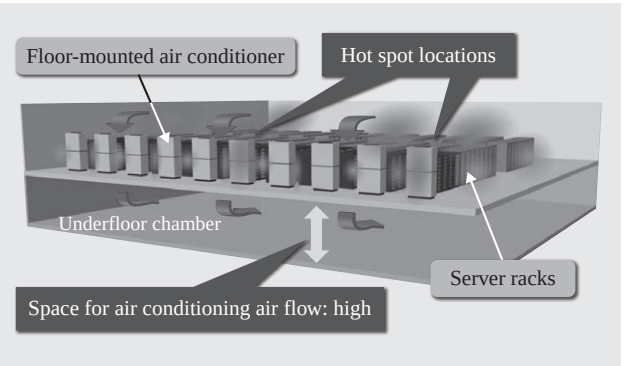

Fig. 1—Conventional Data Center Air Conditioning System. In addition to a long circulation path for the air conditioning air, the location of the air conditioners on the same level as the server racks results in poor space efficiency.

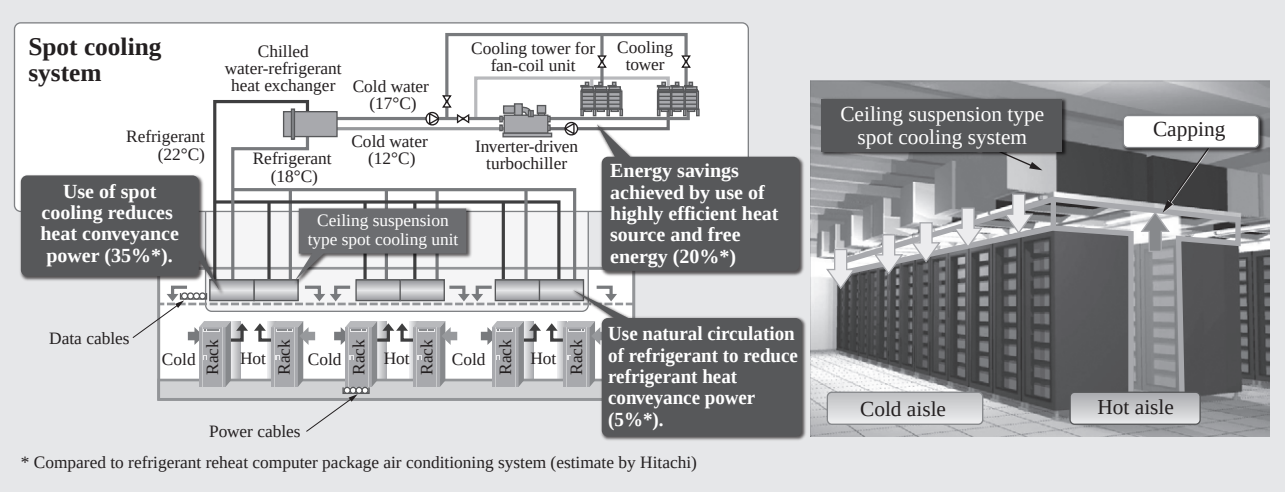

Fig. 2—Overview of Spot Cooling System and Installation Layout.
Air conditioning power consumption has been significantly reduced through the use of spot cooling to reduce heat conveyance power and through energy savings achieved by adopting highly efficient heat sources and a free cooling system. Ceiling suspension type units installed in hot aisles separated by capping draw in hot air and blow chilled air into cold aisles.

SPOT COOLING SYSTEM

Hitachi embarked on the development of natural circulation of refrigerant (in which heat conveyance is achieved without consuming any power) in 2007, and released the spot cooling system featuring highly efficient heat sources in 2009. A modular data center incorporating spot cooling system won a Best 10 New Products Awards from Nikkan Kogyo Shimbun, Ltd. in 2010, and the product range has since been extended by the addition of ceiling-suspension type cooling units and other new components.

System Overview

Spot cooling system consists of chilled water-refrigerant heat exchangers (condensers) that cool the refrigerant, and spot cooling units (evaporators) that cool the air expelled from the servers in the room. For its heat sources, the system uses highly efficient chillers and also free cooling units that use outdoor cold sources to produce chilled water in winter and intermediate seasons. The chilled water cools and condenses the refrigerant in a condenser, and this liquefied refrigerant is gravity-fed to an evaporator that is located at a lower level than the condenser, cooling the air expelled from the servers in the process (a refrigerant pump is used if insufficient head is available for natural circulation). Heat from the ICT equipment is drawn by suction from adjacent hot aisles and cooled air is returned to cold aisles, thereby shortening the circulation path for the air conditioning air and significantly reducing power consumption compared to previous refrigerant reheat type packaged air conditioners (see Fig. 2).

Benefits of System Installation

The spot cooling system uses ceiling suspension type spot cooling units (that have recently been added to the product range) installed above hot aisles to shorten the circulation path for air conditioning air and reduce the required heat conveyance power. Together, these and other measures have succeeded firstly in reducing air conditioning power requirements by approximately 60% compared to previous methods[*1]. Secondly, utilization of the ceiling space has improved the space efficiency for an equivalent floor area by approximately 20% and contributed to customer earnings by increasing the floor space available for ICT equipment. Thirdly, floor-to-floor height has been reduced by around 10% because underfloor space is no longer required for air conditioning air flow (see Fig. 3).

EXAMPLE INSTALLATIONS

When building a server room for cloud systems, SoftBank Telecom Corp. installed a spot cooling system that uses natural circulation of refrigerant. Whereas estimates put the average value of power usage effectiveness (PUE), an index of data center energy efficiency, for data centers in Japan at 2.0, the SoftBank facility has significantly improved energy efficiency and reduced its PUE to 1.3 or less measured across the course of a year (see Fig. 4).

*1 Estimate by Hitachi: Comparison between conventional computer air conditioning system and spot cooling system configured with a core system (chilled water-refrigerant heat exchanger with maximum cooling capacity of 60 kW), four spot cooling units (ceiling suspension type, maximum cooling capacity of 15 kW/unit), and optional extras (highly efficient heat source and free cooling system).

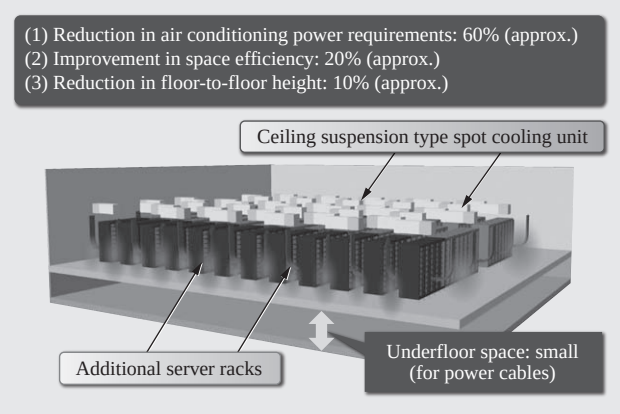

Fig. 3—Benefits of Spot Cooling System.
The shorter distance that the cooling air needs to travel reduces the power required for air conditioning. Meanwhile, utilization of the ceiling area improves space efficiency and also reduces the floor-to-floor height by shrinking the underfloor space requirement.

The features of the installed system are listed below.

(1) Natural circulation of refrigerant

The difference between the specific gravities of the refrigerant in gas and liquid forms means that natural circulation can be used without the need for heat conveyance power.

(2) Ceiling suspension type spot cooling units

Ceiling suspension type spot cooling units are located on top of the server racks where they can cool the exhaust heat close to its source. This shortens the air circulation path and significantly reduces fan power requirements.

(3) Highly efficient heat source system

The energy efficiency of the heat source system is achieved through the use of highly efficient air-cooled chillers and free cooling, in which cooling is performed using cold outdoor air without the need to operate air conditioning equipment.

Fig. 4—Spot Cooling System Installation.
This spot cooling system uses natural circulation of refrigerant and is installed in a server room.

INTERNATIONAL STANDARDIZATION

International standards bodies include the International Telecommunication Union (ITU), International Electrotechnical Commission (IEC), and International Organization for Standardization (ISO), with the ITU being responsible for the field of wireless and fixed-line telecommunications. The ITU is increasing its activities associated with international standards for data centers, including embarking on the formulation of a Best Practices for Green Data Centers recommendation with a target date of 2012.

Ministry of Internal Affairs and Communications spent three years on a draft proposal, contracting Hitachi to conduct demonstrations in FY2010.

Testing of Air Conditioning Techniques for Data Centers with High Load Density

The testing covered four cooling techniques: (1) spot cooling, (2) conventional air conditioners that provide air conditioning throughout rooms housing ICT equipment, (3) outdoor air cooling that utilizes cold air from outside directly for cooling, and (4) evaporative cooling that utilizes the evaporative cold source obtained by spraying water into outdoor air. Experimental data was collected under the actual weather conditions found in the Tokyo region and estimates produced to assess each technique (see Fig. 5)

Relationship between Air Conditioning Technique and Power Consumption

The evaluation was conducted using heat sources under the same conditions, and with use of highly efficient heat sources and free cooling excluded. Under these conditions, the evaluation results reflected the characteristics of each technique, including spot cooling only requiring a low level of air heat conveyance power, and outdoor air cooling using less heat source power because the heat source could be shut down in winter and intermediate seasons. Evaporative cooling gave poor results because of the large pressure loss in the evaporator as well as because it is only effective for a short period of the year (see Fig. 6). Estimates assuming a variety of different weather conditions found that outdoor air cooling works best in cold climates where its heat source power use is low, whereas spot cooling is superior in locations such as Tokyo or Singapore that experience comparatively high outdoor temperatures (see Fig. 7).

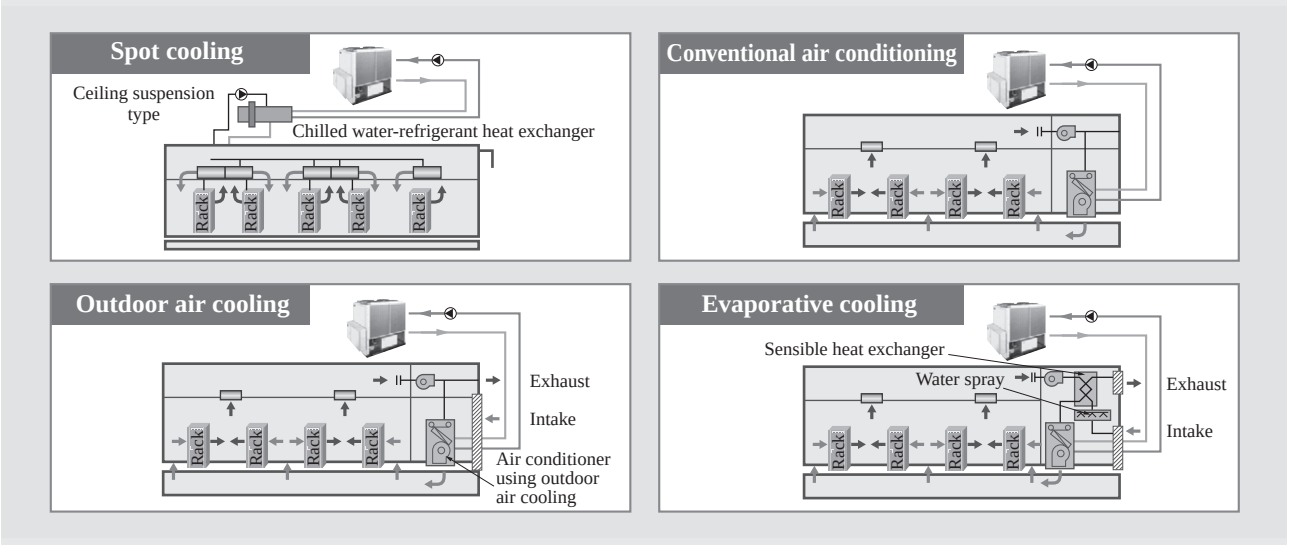

Fig. 5—Comparative Study of Air Conditioning Techniques.
The comparative study considered spot cooling, conventional air conditioning, outdoor air cooling, and evaporative cooling.

Relationship between Air Conditioning Technique and Space Efficiency

Making efficient use of space is also important for data centers, which want to fit as much ICT equipment as possible into the limited space available. Spot cooling can cope with increases in heat density by installing additional units on the ceiling, and without any changes to underfloor space requirements. In contrast, the other techniques not only require more floor space for air conditioners when greater heat generation increases the necessary cooling performance, they also need more space in the underfloor chambers to allow for air flow (see Fig. 8).

ITU Recommendation

Based on these results, Japan presented a draft proposal to the ITU. After a process that included

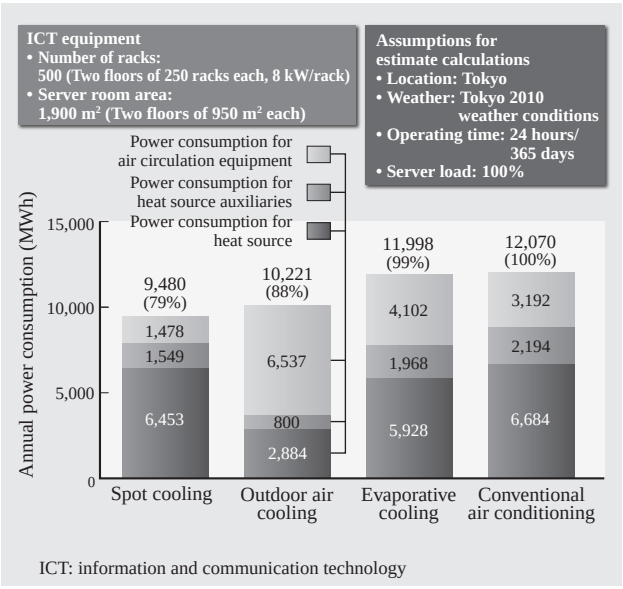

Fig. 6—Results of Comparative Study Under Tokyo Weather Conditions (without High-efficiency Heat Sources).
The results demonstrated that spot cooling requires a low level of air heat conveyance power and that outdoor air cooling uses only a small amount of heat source power.

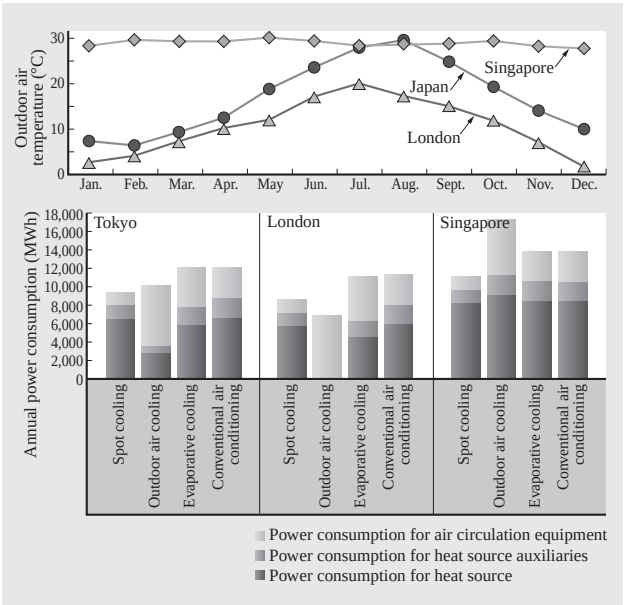

Fig. 7—Comparison of Air Conditioning Power Consumption under Different Weather Conditions (without High-efficiency Heat Sources).
While spot cooling is superior in climates such as those in Tokyo or Singapore, outdoor air cooling is more suitable in the colder climate of London.

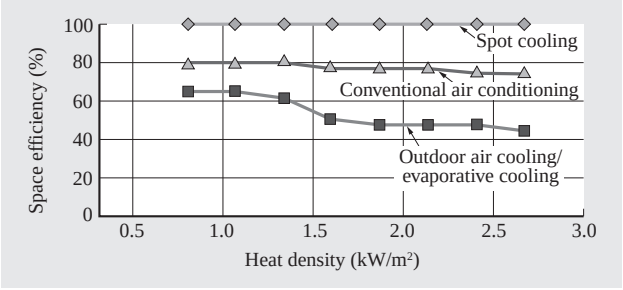

Fig. 8—Heat Density and Space Efficiency.
Spot cooling provides superior space efficiency regardless of the heat density.

an international meeting held in Seoul in September 2011, the draft was accepted in November 2011 and issued as "L.1300 8 Cooling 8.3.2 High Efficiency Cooling Plant."

The L.1300 recommendation states that spot cooling provides superior space efficiency, and recommends use of evaporative cooling or spot cooling and outdoor air cooling, depending on the outdoor environmental conditions (see Table 1).

CONCLUSIONS

This article has described the spot cooling system for data centers, and work on international standardization of data center air conditioning systems.

Spot cooling system consists of spot cooling units that cool the exhaust from ICT equipment in data centers, and chilled water-refrigerant heat exchangers that cool the refrigerant. Compared to previous systems, spot cooling system reduces air conditioning power requirements by approximately 60% and improves space efficiency by approximately 20%. In an actual installation, it significantly improved energy efficiency and achieved a PUE index of 1.3 or less throughout the year.

TABLE 1. Content of ITU Recommendation
The text of the recommendation takes account of outdoor air conditions and space efficiency.

Issues to consider	Cooling technique selection criteria
Considering space efficiency	• Spot cooling is recommended for data centers with high load density [e.g. 5 to 6 kW/rack or higher (1.3 to 1.6 kW/m² or higher)]
Considering outdoor air conditions	• Outdoor air cooling or evaporative cooling are recommended for sites with low wet-bulb temperature (e.g. 15°C or less) because of its energy efficiency. • Spot cooling is recommended for sites with high wet-bulb temperature (e.g. 15°C or more) because of its energy efficiency.
Considering both space efficiency and energy efficiency	• Spot cooling is recommended for temperate climates (e.g. wet-bulb temperatures of 15°C or more) because it provides the best of both space and energy efficiency.

Hitachi has participated in experimental testing aimed at identifying optimum cooling techniques as part of ongoing work toward the formulation of international standards for data center air conditioning. The results of this work indicated that spot cooling delivers the best space efficiency, and provided the basis for a Japanese proposal that was subsequently formalized as an international standard.

REFERENCES

(1) "Outlook for Innovative Energy-saving Technologies for Information and Telecommunications Equipment," Green IT Symposium 2007, Ministry of Economy, Trade and Industry (Apr. 2007) in Japanese.
(2) "Green IT: Facility Solutions Business 2008," Yano Research Institute Ltd. (Oct. 2008) in Japanese.

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