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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

ITU-T L.1300 – Supplement on case study of reduction of air-conditioning energy by optical fibre based thermometry

ITU-T L-series Recommendations – Supplement 9

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Supplement 9 to ITU-T L-series Recommendations

ITU-T L.1300 – Supplement on case study of reduction of air-conditioning energy by optical fibre based thermometry

Summary

Supplement 9 to the ITU-T L series of Recommendations refers to the best practices defined in Recommendation ITU-T L.1300. More precisely, this Supplement provides details of a case study related to the reduction of the energy spent for air conditioning through the use of optical fibre based thermometry. A general description of the temperature measurement is provided, then the optimization process for the air conditioning is highlighted. Finally, the results of temperature measurements made using optical fibre sensors are shown.

History

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Keywords

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ITU-T L.1300 – Supplement on case study of reduction of air-conditioning energy by optical fibre based thermometry

1 Scope

This Supplement describes a case study of reduction of air-conditioning energy by optical fibre based thermometry based on Recommendation ITU-T L.1300. The scope of this Supplement includes:

– a general description of temperature measurement using optical fibre sensors;

– factors used to optimize the air-conditioning environment of data centres; and

– results of case studies of temperature measurements made using optical fibre sensors.

2 Definitions

None.

3 Abbreviations and acronyms

None.

4 Introduction

Information and communication technology (ICT) systems, which support the ICT society, have been expanding remarkably in recent years due to the spread of the Internet infrastructure and deployment of high-performance servers and other high-end computing systems. This trend has been accompanied by a dramatic increase in the floor space required for data centres and the number of servers that they are required to accommodate, which has resulted in a significant increase in the power consumption of data centres.

A data centre has many servers, generally from a few tens to several thousands, and the working servers generate a considerable amount of waste heat. As a result, air conditioning systems using large-scale air-conditioning equipment have become essential for cooling these servers and keeping the room temperature below a specified value. The power required for air conditioning however, has risen to about 40% of the total power consumed by data centres (see Figure 1). Hence, in order to achieve an energy-efficient data centre, reduction of air-conditioner power consumption is unavoidable.

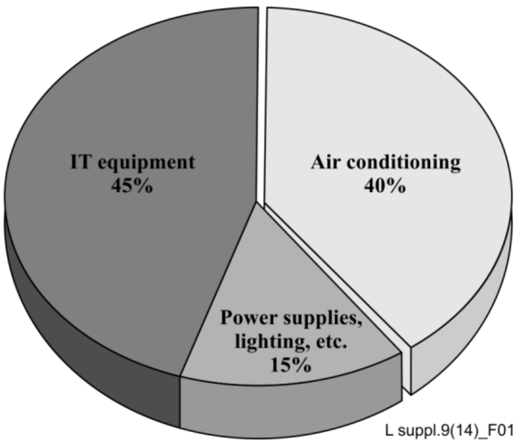

Figure 1 – Energy consumption ratio in data centres

Achieving energy-efficient air conditioning requires not only the deployment of high-efficiency air-conditioning equipment, but also optimization of the cooling conditions at the target locations. The temperature settings in server rooms are often rather low to prevent server overheating, despite the fact that excessive cooling results in energy loss. There is also concern that cooling efficiency would decrease due to a temperature increase of the cooling air that would occur due to exhaust air being drawn back into the system for various reasons, and supplied to points (e.g., server intake panels) designed to be supplied with chilled air.

Thus, to achieve energy conservation by optimizing the air-conditioning system, an accurate and detailed temperature distribution in the vicinity of servers must be obtained. Temperature measurements have traditionally been performed using discrete temperature sensors such as thermocouples, thermistors, platinum resistance thermometer bulbs, or integrated-circuit-type temperature sensors. However, taking into consideration the temperature measurement of a few hundred to several thousand servers, it is impractical to utilize discrete sensors due to several limitations which include high construction cost, difficulty in installation of signal-circuits, difficulty in shortening of measurement time, and so on. Accordingly, to achieve a temperature measurement technique that can handle such a large array of servers, an optical-fibre-based temperature measurement technique has been developed and tested to prove its usability to reduce the energy consumption in data centres.

5 General description of temperature measurement using optical fibre sensors

5.1 Principle and system configuration

Raman scattered light measurement is widely used in optical-fibre-based thermometric sensing methods. Raman scattered light is generated in a transparent substance when irradiated with a strong LASER stimulating light. Raman scattered light consists of two types of light rays called anti-Stokes light and Stokes light. Anti-Stokes light has a 50 nm shorter wavelength than the injected light, and it is sensitive to the temperature changes in the optical fibre. Stokes light has a 50 nm longer wavelength than the injected light and it is not as sensitive to temperature changes. By measuring the intensity ratio of these two types of light, the temperature distribution along the entire length of an optical fibre can be determined.

In more detail, a LASER light in the form of short pulses, with pulse widths of several nanoseconds, is injected into an optical fibre. Then, while the light propagates through the optical fibre, the backscattered intensity of Raman-scattered light generated at various locations in the optical fibre is measured together with the delayed propagation time. The principle behind this technology is shown in Figure 2. The change in intensity versus propagation time is plotted (see Figure 2, upper right). Signal conversions from propagation time to fibre distance and from light intensity to temperature (see Figure 2, lower right) gives the temperature distribution along the fibre. The distances of locations are computed by multiplying the delayed propagation time of the Raman scattered light by the speed of the light propagation in the optical fibre (about 2×10^8 m/s). In a 10-km-long optical fibre, for example, excitation light takes about 50 μs to arrive at the other end, which means that temperature information along the entire 10 km of the optical fibre can be obtained within about 100 μs.

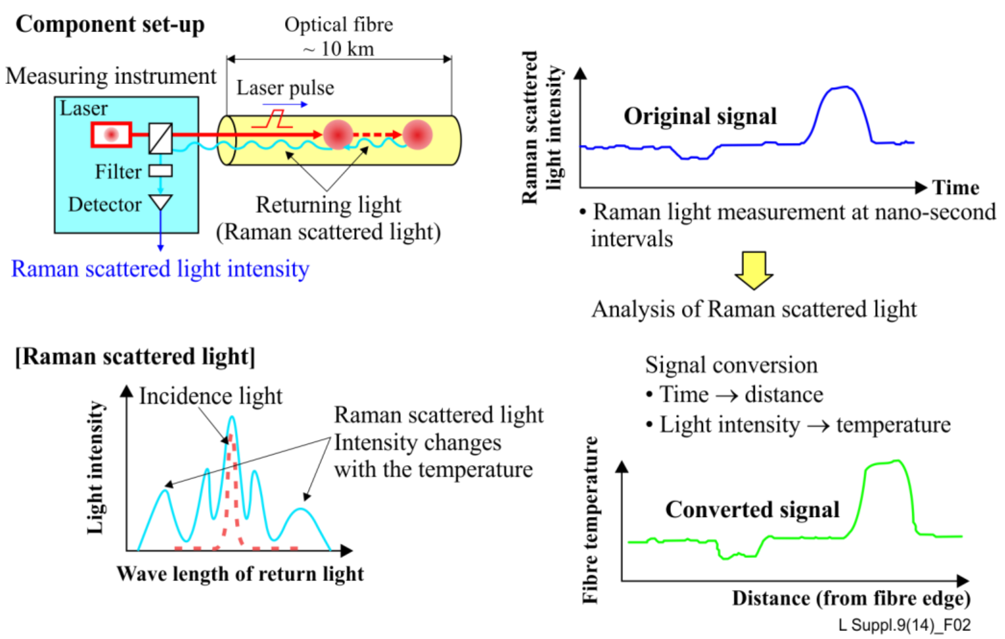

Figure 2 – Principle of temperature measurement by optical fibre

The temperature distribution measurement in optical fibres using Raman scattered light is considered to be very promising for real-time multipoint thermometry.

5.2 Features

Optical-fibre-based thermometry has some excellent features described below:

– real-time multi-point measurement;

since the temperature measurement is carried out based on an optical process, up to 10,000 temperature data points along a fibre laid over a target area can be obtained within every 30 s intervals;

– high resolution and high accuracy;

maximum resolution is 10 cm, and accuracy is ±1°C;

– provides the capability to visualize temperature distribution.

By utilizing high resolution thermometry given above, the temperature distribution in a data centre can be obtained as thermographic image data. A user can easily understand the thermal environment of the data centre, and use of this information would help to improve the air-conditioning efficiency.

6 Optimizing air-conditioning environment of data centres

According to the temperature distribution, the air-conditioned environment energy efficiency can be improved by optimising several air-conditioning parameters. For example, air flow direction, flow rate, and temperature control settings are the most effective parameters for improving the energy efficiency.

7 Case studies

7.1 Basic optical fibre layout

A representative optical fibre layout is shown in Figure 3. The rack installation pattern is almost rectangular along each front side and back side door frames. Optical fibre laid on the front side door is more important to monitor the temperature of the inlet cooling air to each server. Optical fibres on each door were connected together at the base of each server rack to make a single optical fibre circuit.

Fibre was attached to the ceiling in a parallel pattern with a spacing of 30-50 cm and 10-30 cm above from the top of server racks.

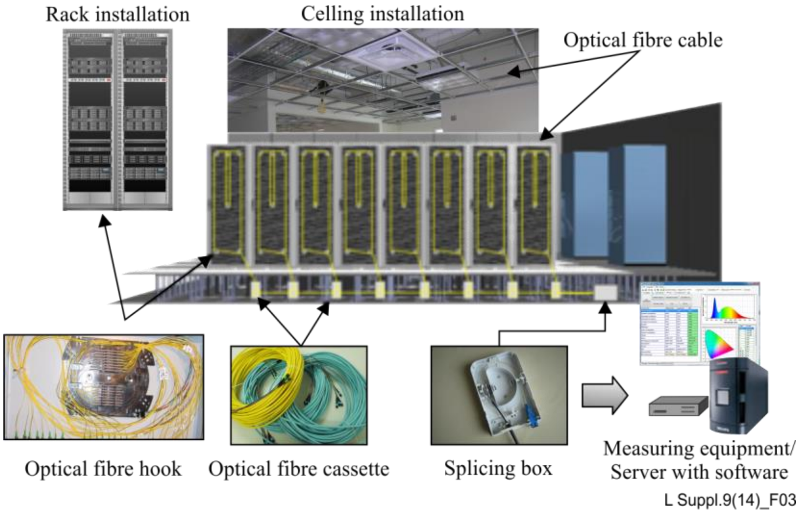

Figure 3 – A typical optical fibre layout in a data centre

7.2 A trial at a compact server room

A trial of site temperature measurements was conducted to improve the air-conditioning environment at a small server room; Fujitsu Kyushu Office. The server room was equipped with 14 server racks and 2 indoor air-conditioner units (see Figure 4).

First, a conventional air-conditioning system was studied (see Figure 4-(A)). From the data, it was found that the cold air from the air-conditioner was blowing in a direction almost straight and parallel to the longitudinal direction of the server room. In this condition, supplied cold air was mixed with the hot exhaust from the servers, and the cooling efficiency of the severs was found to be rather low. Then, tuning of the wind direction and temperature setting were done while monitoring the temperature distribution using the optical fibre thermometry system.

Case 1: By changing the cold air direction as shown in Figure 5-(B), cooling efficiency was improved; this made it possible to increase the air-conditioner temperature. In this case, power consumption of air-conditioning system was reduced by 11%.

Case 2: Without changing the cold air flow direction of case 1, one air-conditioner was stopped (see Figure 5-(C)). Here, it was found that it is possible to supply cold air below 28°C to all servers. From these two changes, it was possible to reduce the power consumption by 36% compared with the conventional conditions.

Case 3: Another air-conditioner was stopped while keeping all the other conditions of case 2 unchanged (see Figure 5-(D)). In this case, air-conditioning power consumption reduction was reached to 23%. Results of the above improvements are summarized in Table 1.

Tuning of wind direction can be completed within 30 minutes for all cases. After tuning, it took 1 to 2 hours for measuring and verifying power consumption of the air conditioner.

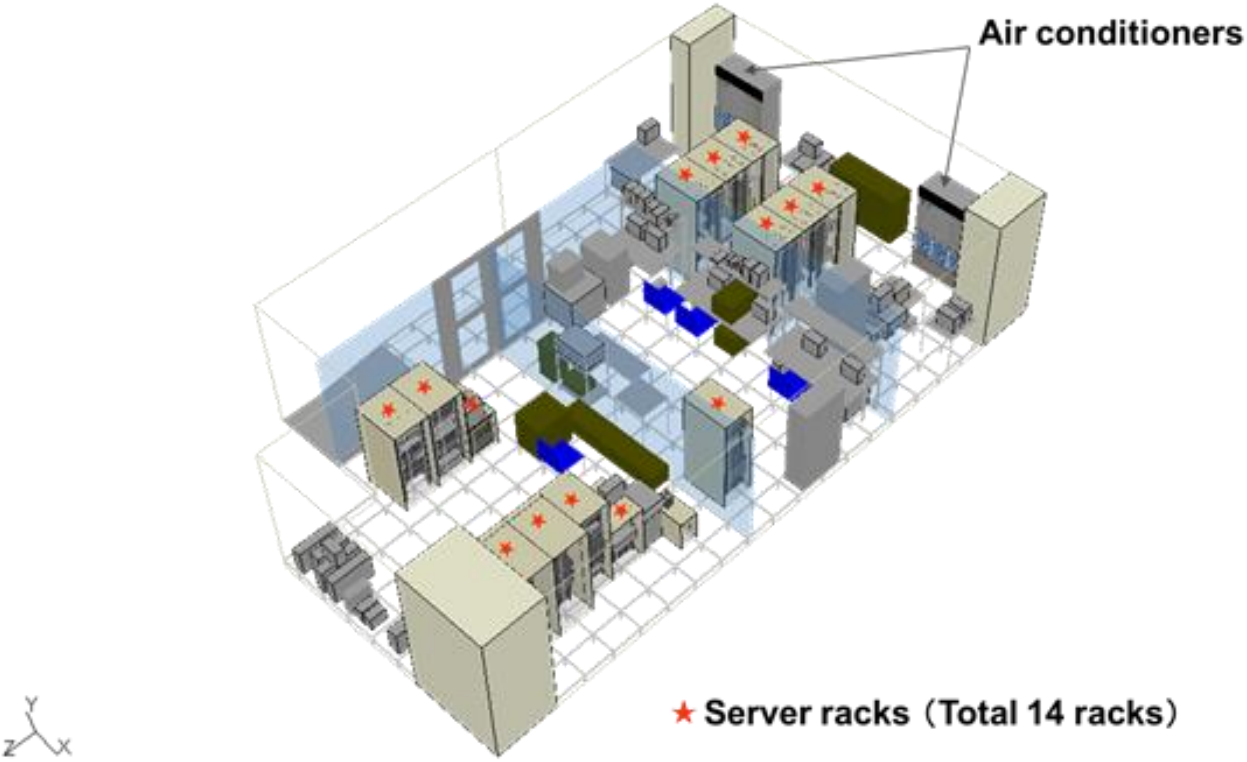

Figure 4 – Server room layout

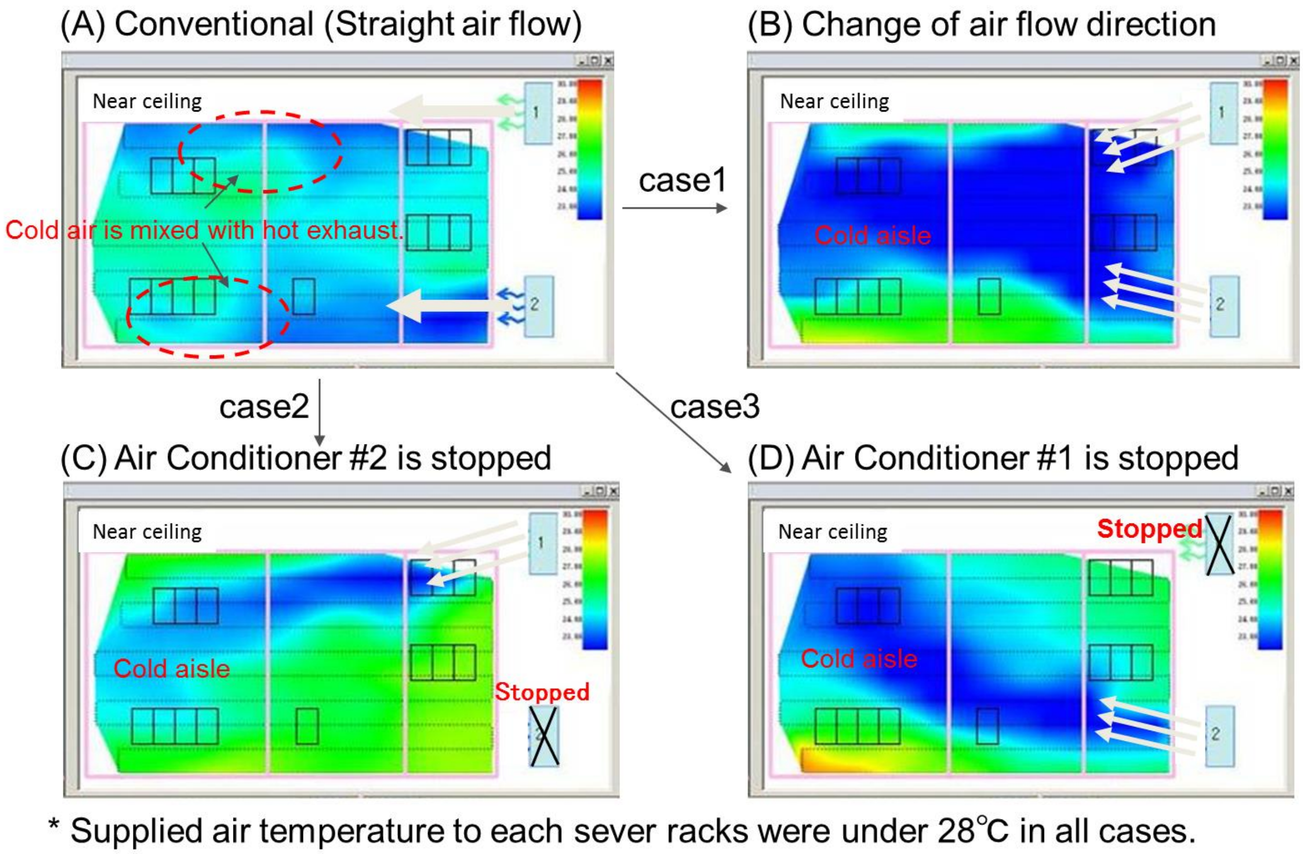

Figure 5 – Changes in temperature distribution due to variation in air flow direction

Table 1 – Summary of improvements for air conditioning

Cooling condition		Set temp. of air conditioner#1	Set temp. of air conditioner#2	Air flow direction	Total power consumption of air conditioners (kW)		Reduction rate
					Indoor unit	Outdoor unit	
Conventional		22°C	23°C	Mixed with hot exhaust	5.6		–
					2.3	3,3	
Case 1	Change of air flow direction	24°C	24°C	Supplied to cold aisle	5.0		11%
					2.3	2.7	
Case 2	Stop AC#2	24°C	Shutdown	Supplied to cold aisle	3.6		36%
					1.2	2.4	
Case 3	Stop AC#1	Shutdown	24°C	Supplied to cold aisle	4.3		23%
					1.2	3.1	

7.3 A trial at a large data centre

Another trial was conducted in a large data centre; Fujitsu Numazu Cloud Centre.

Optical fibre sensors were installed on more than 30 racks and more than 170 m^2 ceiling area (see Figure 6).

Figure 6 – A photograph of the target data centre (Numazu)

In this data centre, the initial set temperature of the air-conditioner was 19°C, and it was found that there were several overcooled server racks (see Figure 7, left). The set temperature was gradually raised, and temperature distribution of all of the server racks and ceiling area was continuously measured to check whether abnormal temperature rise has occurred. When the set temperature reached to 2°C above the original value (19°C), some overheated spots appeared on the front side door of server racks (see Figure 7, right). To prevent any failure, this approach was interrupted immediately, and the cause of this problem was investigated.

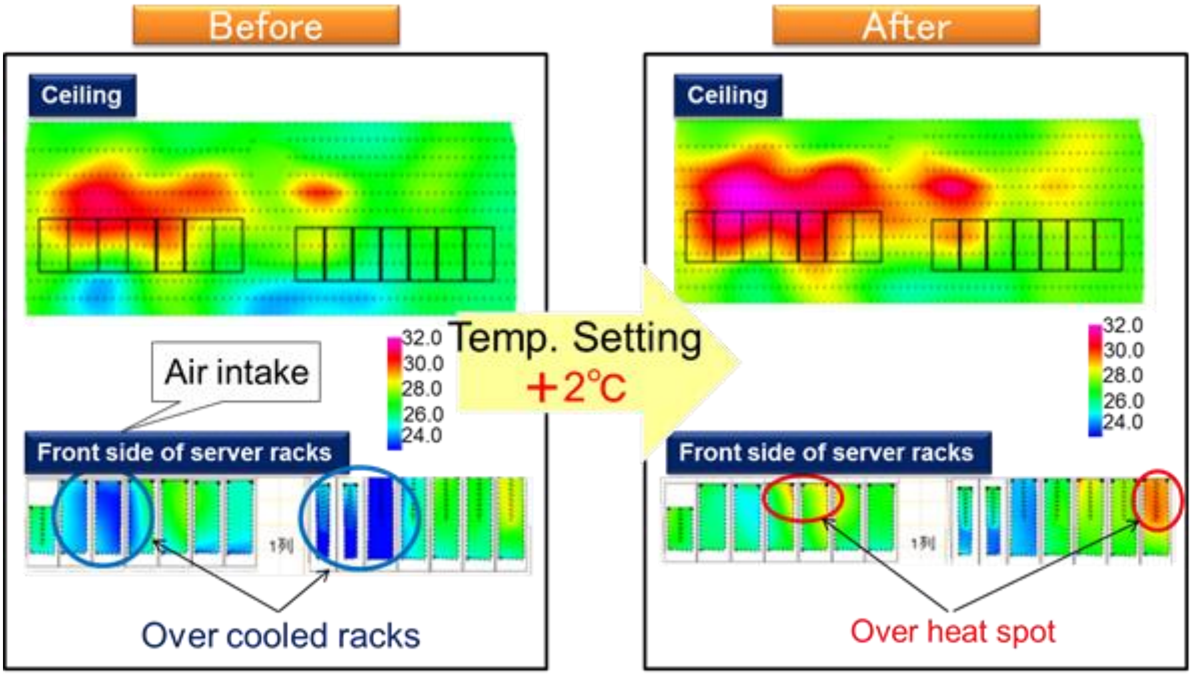

Figure 7 – Result of rising for temperature setting of air-conditioner

By detailed examination around the server racks, 2 types of problems were identified.

1) Hot exhaust backflow

It was found that there were some vacant spaces in some server racks near to the hot spots. It is believed that hot exhaust returned to the front side through these vacant spaces (see Figure 8, left).

2) Insufficient cooling air flow

Cooling air was supplied through several floor grills to each server rack. It was noted that the floor grills had been placed unevenly. This led to insufficient cooling of the servers adjacent to the troubled server racks (see Figure 9, left).

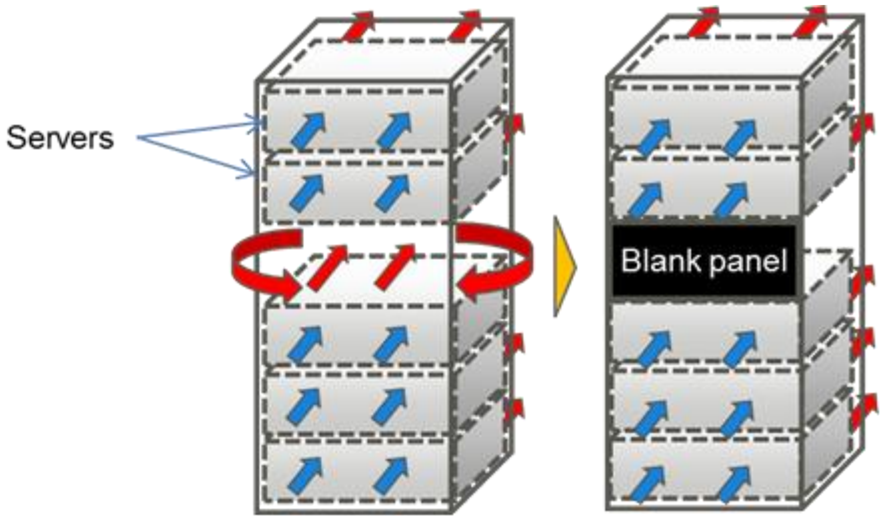

Figure 8 – Air flow around servers in a server rack

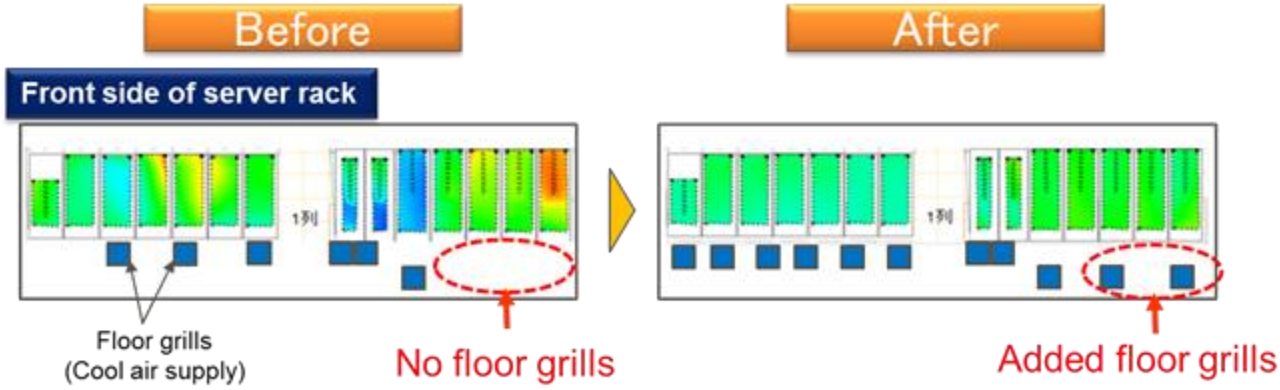

Figure 9 – Installed position of floor grills

Improvement of air flow was carried out as follows:

– Blank panels were installed to the vacant spaces in the server racks.

– The number of floor grills was increased, and installing positions were adjusted while checking the temperature distribution continuously.

As a result, highly uniformed temperature distribution on each server rack was achieved, and the set temperature was able to increase further. As the final result, the data centre set temperature was able to increase by 5.5°C (see Figure 10). Although this study was conducted in only a part of the data centre, the power consumption reduction of air-conditioning system of the entire data centre was estimated to be about 6%.

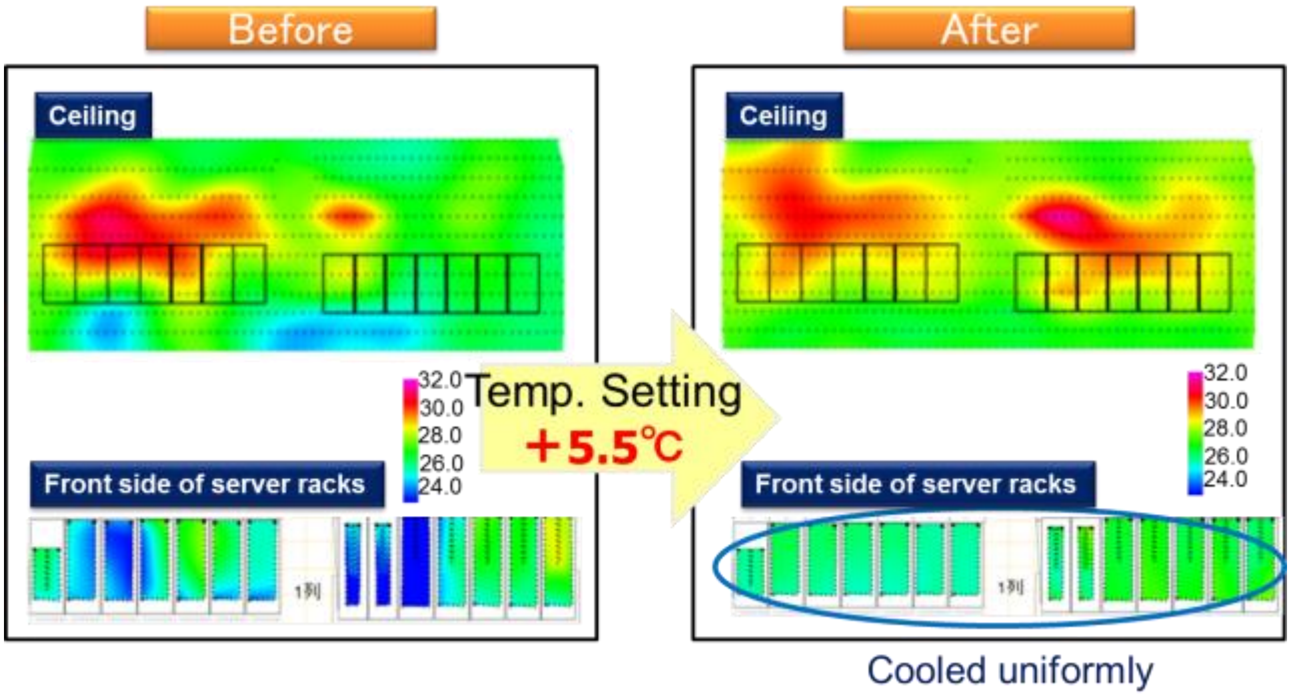

Figure 10 – Improvement of temperature distribution

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[b-ITU-T L.1300] Recommendation ITU-T L.1300 (2011), *Best practices for green data centres*.

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