R&D of Cooling Technology for Energy-Saving in Electronic Equipment or ICT

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Abstract

This paper introduces examples of our R&D aimed at energy-saving cooling technologies by focusing on the air-cooling technology used with LCD projectors, a water-cooling technology used with computers and a phase-change cooling technology. These technologies feature low power consumption cooling devices for information and communications technology (ICT) equipment such as the computers and projectors used in the office environment.

Keywords

projector, computer, air cooling, water cooling, phase-change cooling

1. Introduction

Offices contain a large number of ICT devices such as computers and projectors. In order to operate office ICT equipment in a stable manner it is necessary to design the cooling system so that the temperatures of the heat-generating components and the devices inside the equipment do not exceed the specified temperatures. In general, ICT equipment is cooled mainly with air-cooling by blowing air from a fan incorporated in the equipment or with water-cooling by circulating a coolant such as water and using a pump. In addition, the phase-change cooling method has recently been put into practical use. This method circulates the coolant based on the phase change between evaporation and condensation, without the need for a pump.

The cooling of devices necessitates additional consumption of power for driving the cooling components such as the fan and the pump (hereinafter referred to as the cooling power). In this paper, we will discuss details of the energy-saving cooling technologies used in various cooling methods based on R&D for minimizing the cooling power that has been conducted at our NEC System Jisso Research Laboratories.

2. Actual Case Studies of Cooling Methods

This section introduces the air-cooling, water-cooling and phase-change cooling technologies developed at the NEC System Jisso Research Laboratories using actual case studies.

2.1 Air–cooling Technology

The air-cooling method is adopted by much ICT equipment thanks to the low cost of the cooling components and the ease of maintenance. As a typical case of energy-saving technology for air-cooling, this section introduces the “impinging jet cooling technology” developed for LCD projectors.

(1) LCD Projector Cooling Technology

The LCD projector as shown in **Fig. 1** emits colors by applying the light of a lamp to the LCD panels in R (Red), G (Green) and B (Blue) colors. Since the life of the LCD panel decreases under high operating temperatures, the panel surfaces are cooled by blowing air onto them using fans. When the brightness of the projector is increased, the conventional measure has been to increase the rate of the airflow from the fans.

(2) Impinging Jet Cooling Technology

The form of thermal migration between the surface of a heat-generating body and a fluid such as air flowing on it is called heat transfer. Heat transfer can be activated by increasing the rate of the air flowing on an LCD panel surfaces, but this leads to an increase in the power required for driving the fans. Therefore, the NEC System Jisso Research Laboratories developed a method for activating the heat transfer without increasing the airflow rate. This method blows air from both the upward and downward directions of each LCD panel so that the airflows impinge on each other. This technique aims at initiating the heat transfer activation effect by disturbing the airflow on the surface of a heat-generating body.

Fig. 2 compares the cooling performance with that of the

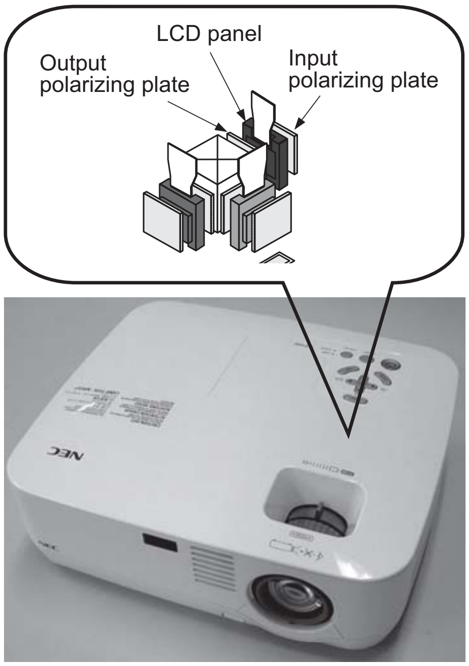

Fig. 1 LCD projector.

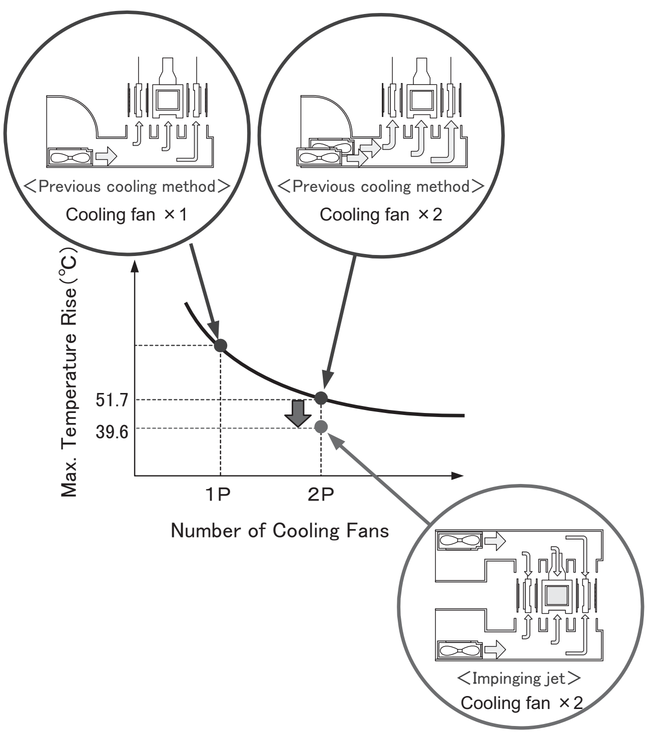

Fig. 2 Results of impinging jet cooling performance.

traditional cooling method that blows air only from one side of the LCD panel. It is confirmed that the LCD panel temperature can be reduced by 20% when the fan drive power remains the same as for the former method. When the fan drive power is used for keeping the LCD panel temperature at a certain temperature, the required fan drive power is almost halved compared to that of the traditional method. An additional feature of the impinging jet cooling technology is that it can suppress variation in the LCD panel surface temperature, which had previously increased on the lee side when using the traditional cooling method. The use of this technology has resulted in the additional effect of reducing the projector color irregularities that had been caused by irregular temperature distribution on the LCD panel surface.

2.2 Additional Items

One of the big differences between the air-cooling and water-cooling methods is the possibility of effective utilization of the heat radiating area of the heat radiator. This section introduces a case study of a water-cooling module that adopts an energy-saving technology.

(1) Comparison of the Air-cooling and Water-cooling Technologies

When the heat generation amount of a cooling target device such as a computer CPU increases, the heat sink is installed above the device in order to increase the amount of the heat radiation. In the case of air cooling, however, even when the heat sink size is increased according to the increase in the amount of the heat generation of the device, efficient heat radiation is possible only from the section closest to the device. This phenomenon is due to the heat transmission loss derived from the heat conduction of the metallic material. In consequence, in order to reserve a heat radiation amount that matches the heat radiation amount of the device, it is required to increase the heat transfer, i.e., to increase the airflow rate from the fan.

On the other hand, with water-cooling, the total area of the heat radiator can be used effectively because the heat carrying coolant, such as water, can be circulated on the heat radiator. This means that the airflow rate from the fan can be low for water-cooling. As a result the reason that the water-cooled PC is quiet is that the fan rotation speed can be reduced thanks to the possibility of cooling with a slower airflow rate from the fan.

(2) Water-cooling Module

The water-cooling module is composed mainly of a heat-receiving section that is connected to the device, the heat-radiating section that radiates the heat carried in the air, and the pump that circulates coolant between the heat-receiving and heat-radiating sections. In order to prevent deterioration in the ease of incorporation in the ICT equipment as well as in maintenance, the NEC System Jisso Research Laboratories has developed water-cooling modules that are interchangeable with air-cooling heat sinks by fabricating the water-cooling components summarized above in the same sizes as those for the traditional air-cooling heat sinks. As an example, **Fig. 3** shows the comparison of cooling power between a water-cooling module with width, height and depth all of 100 mm and a copper air-cooling heat sink of the same size.

Using a square-shape heat-generating body of 20 mm per side, we increased its heat generation amount and compared the power required for cooling the heat-generating body at a temperature 50°C higher than the atmospheric temperature. The cooling power refers to the fan drive power with air-cooling, but is the sum of the fan drive power and pump drive power in the case of water-cooling. The pump used in this case is 4 W. The results of comparison show that, due to the power required for driving the pump for water cooling, air cooling can cool the device with less energy if its heat generation amount is no more than 230 W and water cooling can cool it with less energy when the heat generation amount is 230 W or more.

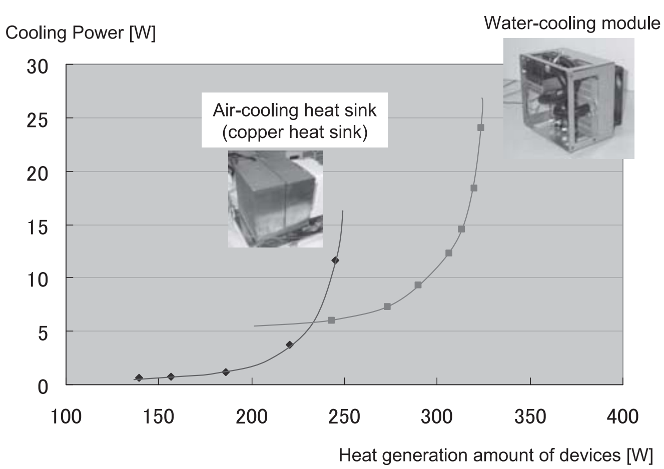

Fig. 3 Comparison of cooling power for air- and water-cooling modules.

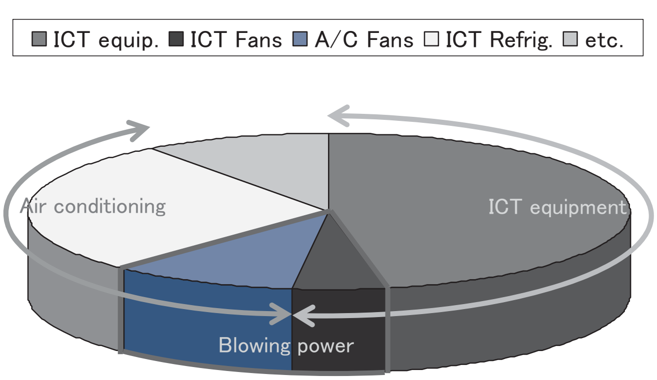

Fig. 4 Power consumption details of the server room.

(3) Blowing Power of Air Conditioner for Cooling of ICT Equipment

When making a decision on the method of cooling ICT equipment, it is also necessary to consider the power for the office air-conditioning. Let us assume that the server room is installed in an office building. Usually, a dedicated air-conditioner is installed to cool the servers in the server room and it consumes power equivalent to the total power consumed by the servers. The details of the power consumed in the server room are shown in **Fig. 4** . The sum of the power of the driving fans inside the servers and that for supplying cool air to the fans from the air conditioner occupies 10 to 20% of the total power consumption of the server room.

If the servers use a cooling method that requires a large amount of cool air for cooling, the air conditioner has to supply a large amount of cool air, so the total power consumption of the office building will increase.

It is therefore necessary to consider the total power consumption of the building when making decisions on the cooling method of ICT equipment for the office.

2.3 Phase-change Cooling Technology

The water-cooling technology can reduce the fan drive power but necessitates the addition of pump driving power. Below we introduce a phase-change cooling technology that can circulate coolant without the need of a pump.

(1) Operating Principles of Phase-change Cooling

As shown in **Fig. 5** , the phase-change cooling method circulates coolant using the buoyancy produced when a coolant such as water changes to vapor and the gravity when the vapor returns to liquid.

With water-cooling, the temperature returns to the original while the heat is radiated to the atmosphere. When water is used as the coolant, heat of 418 kJ/kg can be migrated for a

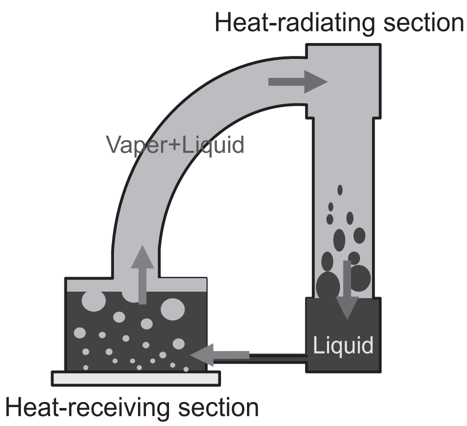

Fig. 5 Coolant action of the phase-change cooling technology.

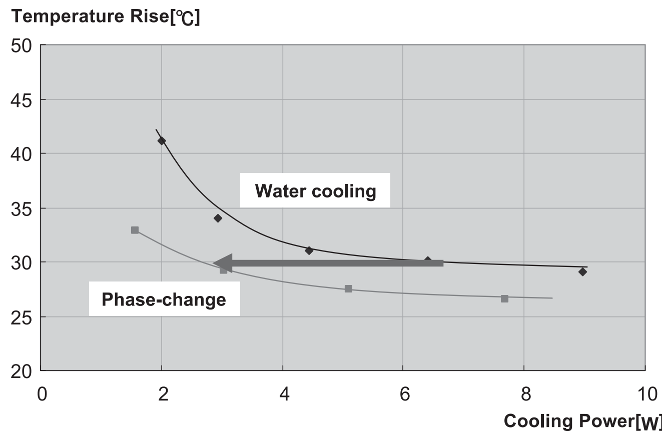

Fig. 6 Comparison of cooling power.

Photo View of mounted phase-change cooling module.

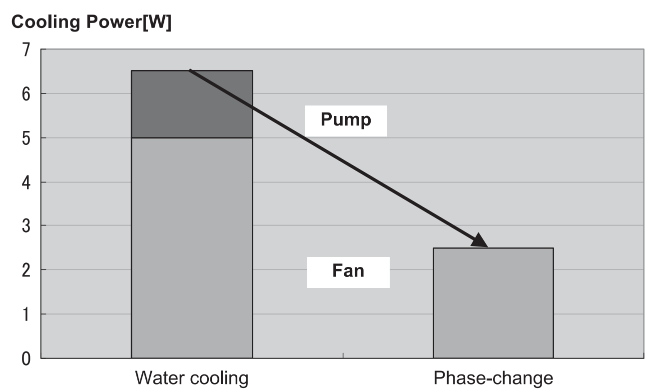

Fig. 7 Cooling power details.

temperature change of 100°C. The heat released in this way is called "sensible heat." On the other hand, with phase-change cooling, the heat is migrated when the coolant changes from liquid to vapor and from vapor to liquid phases. When water is used as the coolant, heat of 2,440 kJ/kg can be migrated with several times higher efficiency than water-cooling. The heat released in this way is called the "latent heat."

(2) Cooling Power of Phase-change Cooling Technology

We compared the cooling power between water-cooling and phase-change cooling by incorporating a 115 W CPU in the NEC workstation Express 5800/54Ca. **Photo** shows the phase-change cooling module mounted in the workstation.

As shown in **Fig. 6** , the higher cooling capability of the phase-change cooling method allows it to reduce the CPU temperature by a greater amount than for water-cooling when the same cooling power is used. The cooling power required to cool the CPU temperature to 30°C above the atmospheric temperature is 6.5 W with water-cooling and 2.5 W with phase-change cooling. The details of the cooling power are shown in **Fig. 7** .

The figure shows that phase-change cooling makes it possible to save the pump drive power of 1.5 W because it does not use a pump. Furthermore, thanks to the heat migration with latent heat, the fan drive power can be halved compared to water-cooling.

3. Conclusion

In the above, we introduced energy-saving cooling methods for use with information and communications technology (ICT) equipment such as projectors and computers in an office environment. Although the share of the fan drive power in the total power consumption of the ICT equipment is as small as a few percent, the power consumed by the air conditioner of the office building for cooling the ICT equipment is connected directly to the inherent cooling efficiency of the ICT equipment. At the NEC System Jisso Research Laboratories, we are conducting R&D into energy-saving cooling technologies by considering not only the ICT equipment issues but also by aiming at optimizing the environment in which the ICT equipment is installed. In thus working toward the realization of a society that values a low environmental load it is our intention to continue technical developments aimed at further reducing customer energy consumption.

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