“Cooling System Technology that leads clients' business to success”

High Cooling Performance/Low Noise Measures: High Performance Liquid Cooling System

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1. Introduction

The heating value of devices has tended to rise in recent years, reflecting the increasingly high-speed and high-performance nature of information equipment such as personal computers. The heat density in devices has also been rising with miniaturization and high density mounting. Technical advances in microprocessor units (MPU), which serve as the brain of computers, have been especially remarkable, with continual gains in speed, performance and capacity. Accompanying these gains, the heating value of microprocessors has been rising rapidly. That in turn increases the need for a cooling device with high cooling performance, to cool the microprocessor.

Another recent trend has been growing demand for information equipment to generate less noise, as an environmental measure.

SANYO DENKI has been developing cooling devices that respond to these demands for high cooling performance and reduced noise.

But we believe that the needs of our customers will continue to rise in the future. And conventional cooling devices using the air cooling system may ultimately be unable keep pace.

Anticipating that situation, we have been developing a cooling device that employs an alternative technology in the form of a liquid cooling system.

This paper discusses the technical problems of the conventional air cooling MPU cooler, and introduces the new liquid cooling system developed by SANYO DENKI.

For more details, please refer to the article introducing the new product: “High Performance Liquid Cooling System SAN ACE MC Liquid” in this series.

2. Issues with the Conventional Approach

To respond to growing demand from customers for better cooling performance, SANYO DENKI has introduced cooling devices for microprocessors using the air cooling system. This system consists of a cooling fan and heat sink.

The structure of a typical air cooling MPU air conditioner is explained as follows.

An air cooling MPU cooler consists of three parts: a fan motor, a heat sink, and thermal interface material (TIM). Heat from the MPU is conducted to the heat sink through the TIM. Heat conducted from the MPU is diffused throughout the heat sink because the heat sink material has excellent heat conduction. Aluminum, cooper or a combination of the two are used for the main currents of the heat sink, balancing performance and manufacturing cost. In addition, a fin is used to generate a heat radiation effect by enlarging the surface area of the heat sink as much as possible. The fan motor is added to force wind towards this fin.

Fig. 1 shows an example of an air cooling MPU cooler.

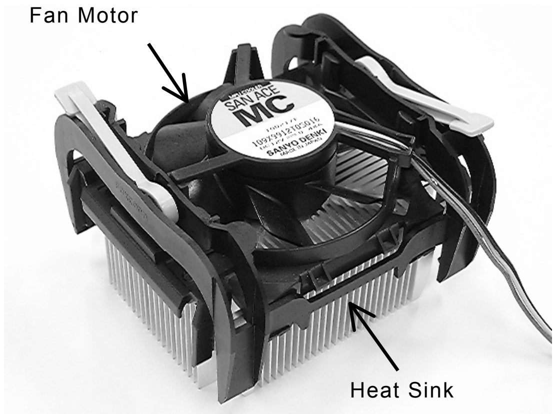


Fig.1　Example of an Air Cooling MPU Cooler

The air cooling MPU cooler generates greater heat conduction from the heat sink into the air by using the fan motor to force air into the heat sink.

Heat conduction from the heat sink into the air is based on the following concept.

The concept is called convection heat transfer, in which heat moves from a solid wall to fluid when the fluid flows along the surface of the solid, as shown in Fig. 2. When the fluid is forced along by a fan or other means, it is called forced convection heat transfer.

The heat transfer value using forced convection heat transfer can be expressed as shown below. This is called Newton’s cooling law.

$$Q = h \cdot S \cdot (T1 - T2) = h \cdot S \cdot \Delta T \cdots\cdots (1)$$

Q　: Heat transfer value(W)
S　: Surface area of the solid(Heat Sink)(m^2)
h　: Heat Transfer Coefficient($W/m^2 \cdot K$)
T 1　: Surface temperature of the solid (℃)
T 2　: Temperature of the fluid (℃)
ΔT　: Temperature difference (T 1-T 2) (K)

This shows the degree of ease of heat transfer. The larger the transfer, the greater the heat transfer coefficient ($W/m^2 \cdot K$).

It is generally difficult to show the heat transfer coefficient because the value changes significantly, according to the nature of the fluid, the state of fluid flow, and the shape of the solid wall, but is proportional to the 0.8th power of the velocity of the flow in the case of a turbulent flow. When the flow of fluid is a laminar flow, the heat transfer coefficient is in proportion to the 0.5th power of the velocity of flow

Fig. 3 shows the range of a rough heat transfer coefficient.

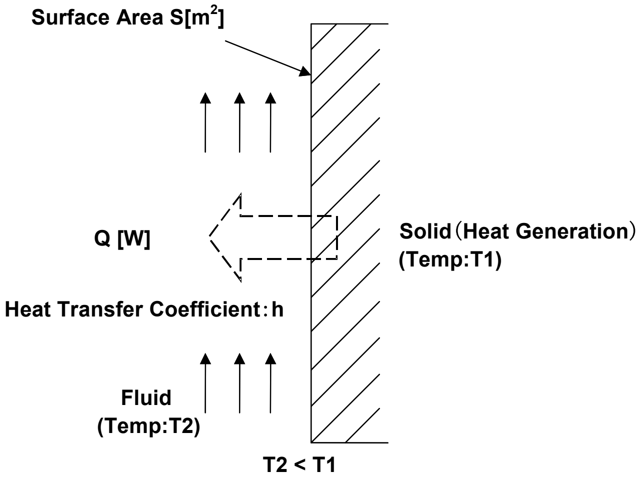
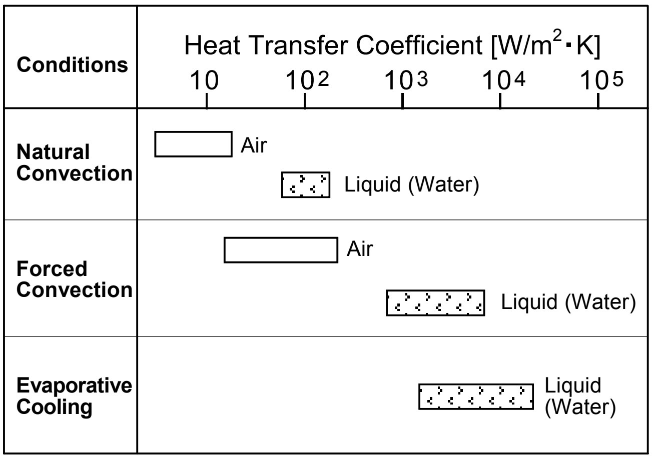


Fig. 2 Movement of Heat by Convective Heat Transfer



※ Flow Velocity of Air : 3～15m/s

Flow Velocity of Liquid : 0.3～1.5m/s

Fig. 3 Outline Value of Heat Transfer Coefficient

(1) As the expression shows, the heat transfer coefficient improves by increasing the surface area. The heat transfer coefficient also grows, by speeding up the flow velocity of air. This improves the heat transfer value.

SANYO DENKI has been using a larger heat sink with larger heat radiation area and a high air volume fan to achieve high cooling performance as the calorific value increases with improvements in the MPU.

This approach has raised new problems, such as increasing size and mass. The heat sink manufacturing technology has become more complex with improvements in the surface area. And noise has increased as the rotation speed of the fan motor has accelerated to generate high air volume.

Nonetheless, we continue to push back the limits of cooling efficiency and noise reduction using air cooling technology.

3. New Demands and Our Response

The Thermally Speed Controlled Fan, the rotation speed of which is changeable depending on the temperature of the inner housing, is now being used for MPU coolers, in response to customer demands for high cooling performance and low noise. Fan rotation speed is suppressed and noise is reduced at low temperatures when there is still a margin in cooling performance. Fan rotation speed is increased to provide cooling as the temperature of the inner housing rises with device operation. The MPU cooler, which combines high cooling performance and low noise, has been commercialized, employing the Thermally Speed Controlled Fan.

We have recently introduced an air cooling MPU cooler that has not only the thermally controlled function, but also a function that carefully controls the rotation speed of the fan based on the state of MPU operation. This helps to reduce the noise generated by information equipment such as personal computers. This function lowers noise by suppressing the rotation speed of the fan when the MPU load is small, which is namely when less heat is generated by the MPU, even if the temperature inside the housing is high.

Consequently, we now have a product that considers noise when it is built into a customer's device, achieving a coexistence of high cooling performance and low noise.

As customers increasingly value silent information equipment, there will be growing demand for cooling devices to generate even less noise.

Responding to these demand, the high performance liquid cooling system, SAN ACE MC Liquid uses the established cooling technology of the liquid cooling system to simultaneously achieve high cooling performance and low noise.

4. New Solution: Liquid Cooling System

The liquid cooling system consists of a cold plate, a radiator, a pump, a tube, and a fan motor. (See Fig. 4)

In the liquid cooling system, a cold plate absorbs the heat from the MPU, and liquid flows on the cold plate the deprive the cold plate of its heat. After removing the heat from the cold plate, the liquid itself is warm, so it is sent to the radiator, and then radiated from the radiator by the air sent by the fan motor. The liquid is thus cooled, and then again circulates around the cold plate once again depriving the cold plate of its heat. An electric pump is used to circulate the liquid.

The heat exchange using the cold plate and radiator is based on Newton's cooling law, explained in clause 2 of this text.

The liquid cooling system is using liquid as a heat transmission medium. Because the heat transfer coefficient of liquid is very high (refer to Fig. 3) compared with air, the liquid can form a cooling system with a large heat transfer value and high cooling performance.

Although liquid cooling is an established technology, it has now begun to be used for information equipment such as personal computers.

The cooling device of the liquid cooling system is a complex structure and there are many parts for the user to assemble, requiring considerable expertise. The air cooling MPU cooler, by contrast, has a comparatively simple structure. Moreover, maintenance, including replenishment, is required, since the cooling liquid volatilizes over time. Another reason why the system has not been adopted in general information equipment may well be because problems of reliability, such as the leakage of the liquid, have not been resolved.

When we developed the liquid cooling system, we designed it in the pursuit of a major improvement in cooling performance over that provided by the conventional air cooling MPU cooler, as well as noise reduction. We also integrated the radiator, reserve tank, pump, and fan to improve ease of assembling and maintenance. As a consequence, we created a highly reliable liquid cooling system.

With our new liquid cooling system, cooling performance has improved about 32%, and noise has been reduced about 23dB[A], assuming the same cooling performance (0.28K/W) as that of the best-perofrming conventional air cooling MPU cooler.

This product has the ability to adequately cool future MPUs with large power consumption. It could also be used as a silent cooling device, since high cooling performance was achieved by lowering the rotation speed of the fan motor to the level needed to cool the MPU.

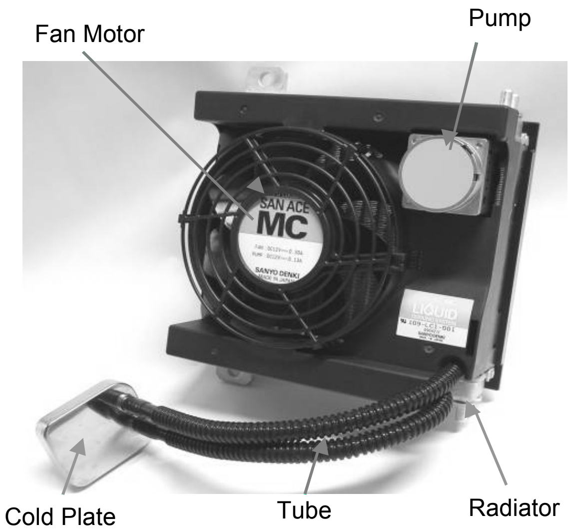


Fig. 4 Structure of Liquid Cooling System

4. Conclusion

This paper has explained that customer demands for MPU cooling devices have reached the stage where improving the performance of cooling device using the air cooling system is now very difficult level.

We then described a cooling system using the liquid cooling system, which has achieved unprecedented cooling performance and low noise.

We are confident that the liquid cooling system we have developed and the technology behind it represent solutions for customers who need both high cooling performance and low noise. We believe that this product will contribute to the success of our customers' businesses.

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