The Cooling Unit for the Closed Box

By

Toshio YASUNAGA*, Hisao KOIZUMI*

(February 1, 1983)

1. Introduction

According to the development of the measuring equipment using microprocessors, the laboratory and factory automations are growing. So that, the desires of using computers under bad conditions, for example, in factories with dusts or bad gases, near coast where damages from sea winds are exist, or outdoors, where they aren't used until now for the reason of such bad conditions, are also growing. In those places, because of such bad conditions, computers can be used onry in clean rooms or something like that.

To use computers under such bad conditions, we made a closed box which protects computers or other electric equipment from such bad conditions. In the case of usual boxes, the heat from the equipment in boxes is cooled with the outer air. So that, to use clored boxes, it is important to cool the equipment in the closed box without air intake.

Then, to cool thee equipment, we made a cooling unit, in which a set of heat-pipe heat exchangers and a tandem-type scirocco fan are set. It transport the heat from the closed box to outer air with heat-pipes. To get high efficiency of heat transfer, heat-pipes with fine fins are used. And, for the maintenance, it has the construction for which it is easy to put it on and off the closed box.

2. The Construction and Works of the Cooling Unit

Fig-1 shows briefly the basical construction of the cooling unit. The box of the cooling is divided into two rooms by a wall. The inner air side room and the outer air side room. Each room has the heat-pipe heat exchangers with alminium fins and a tandem-type scirocco fan.

The heat-pipe heat exchangers pierce the center wall. The inner air, warmed by the heat of the equipment in the closed box, is inhaled from the under side of the inner heat-pipe heat exchangers, cooled by heat-pipes, and breathed into the closed box by one scirocco fan. On the other hand, the other side of the heat-pipes are cooled by the outer air, which is inhaled from the roof of the cooling unit, and warmed outer air is breathed out by the other scirocco fan. In this process, the closed box can be cooled without the outer air inflow.

Fig-2 shows the appearance of the cooling unit. There is a wall at the center of the box of the cooling unit. The center motor is set at the wall, and it drives two

* Toshiba R&D Center, Toshiba Corporation

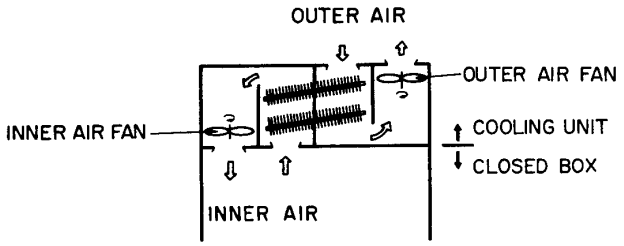

Fig. 1. Construction of cooling unit.

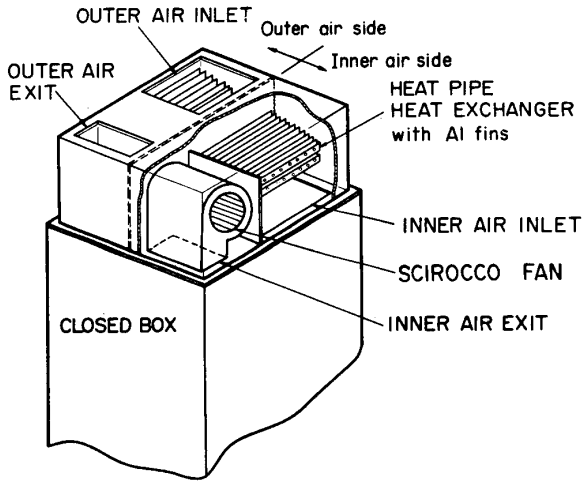

Fig. 2. Cooling unit for closed box.

scirocco fans, one is in the inner air side room and the other is in the outer air side room.

The cooling unit has the following characteristics.

(1) For the purpose of the improvement of the heat transfer between two air flows and heat-pipes, the containers of the heat-pipes are made of copper tubes with fine alminium fins, which are used for the heat exchangers of the air conditioner systems. The fin pitch is 2 mm. The fin thickness is 0.2 mm. And 8 pipes are arranged like a slab (600*200*20) with a set of alminium fins. The heat transfer area of pipes with fins increases more than 20 times that of copper tubes only.

(2) The heat-pipes are thermosyphon type without wick. For the degrease of the height of the cooling unit, the heat-pipe heat exchangers are slanted. (The angle is about 10°.) This cooling unit has two heat-pipe heat exchangers.

(3) The coolant of the heat-pipes is R-12. The volume of it is about one third of the total volume of heat-pipes containers.

(4) A tandem-type scirocco fan is used. The center motor is set at the outer air side of the center wall of the cooling unit. One fan is set in the outer air side room, and the other is set in the inner air side room. This fans are big and rotate alowly, so that they make very low noise.

(5) The cooling unit is set on the top of the closed box instead of the roof pannel of it. Because of this construction, the installation and removal are so easy that it is convinient to maintain it.

Table 1. Main spec of cooling unit

Temperature rise	10–15 k/580 W
Heat pipes	8/Stage
Coolant	R-12
Air driving fan	Tandem-type scirocco fan
Dimension	533×683×223

Table-1 shows the main spec of this cooling unit.

3. The Heat-Pipes

Before the trial product of this cooling unit, we tested the heat transport capacity of the heat-pipes. The inner air side of the heat-pipes for this test is without fins and a ribon heater is wrapped there. And the other side of the heat-pipes, which is the outer air side, is cooled by a fan.

Fig-3 shows this results. The vertical axis indicates the temperature difference between both ends of the heat-pipes (K), and the horizontal axis indicates the transfered heat by the heat-pipes (W). The angle of the heat-pipes, 0, and the ratio between the coolant volume and the container volume of the heat-pipes, V_1/V, are two parameters.

The thermal resistance of the heat-pipes at $0=10°$ is less than that at $0=90°$. It seems that the disturbance of the coolant, which is caused by the growth of bubbles in the coolant, promotes the heat transfer in the heat-pipes. At $0=90°$, the disturbance seems to be suppressed by the coolant head. In the region of low heat loads, the relation between the temperature difference and the heat flow is not linear. In this region, the disturbance of the coolant seems to grow.

Fig-4 shows the effects of the coolant volume in detail. In both cases, $0=10°$ and $0=90°$, the smallest thermal resistances are at about $V_1/V=1/3$. Then the coolant volume of the heat-pipe heat exchangers of the cooling unit is decided one third of the total volume of the heat-pipes' containers.

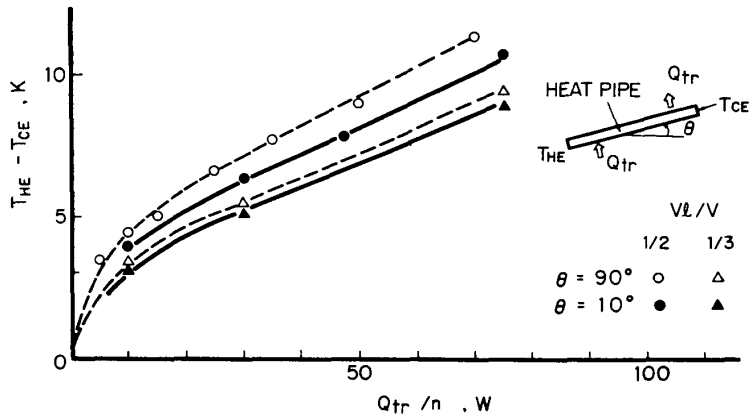

Fig. 3. Heat test os single Heat pipe.

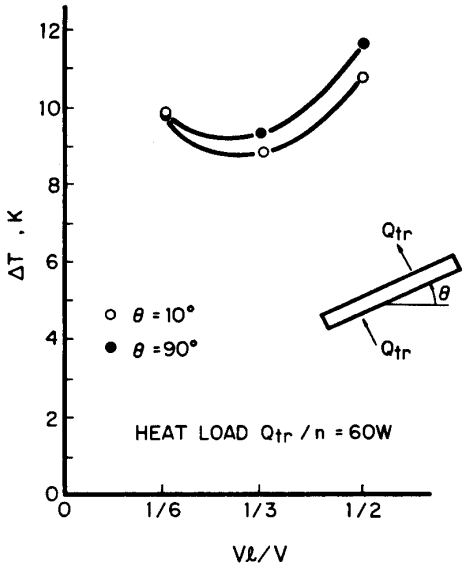

Fig. 4. Effect of volume ratio of coolant.

4. The Thermal Test of the Cooling Unit

Fig-5 shows roughly the scheme of the thermal test. Two inlet ducts are attached at both air entrances of the cooling unit. The both flow rates are measured in these ducts and controlled with the rotating speed of the fan. In one duct, which is attached at the entrance of the inner side air, a sheathed heater is set. This heater simulates the heat of the equipment in the closed box. The air temperature of both inner and outer side are measured at both upward and downward flow of the heat-pipes with thermo-couples. At all mesurement points, Plural thermo-couples are set to check the flat temperature distribution in the steams. The heat which is transfered by the cooling unit is decided by following equation.

$$Qtr=0.5RC(Wi(Tiu-Tid)+Wo(Tod-Tou)) \qquad (1)$$

R: density of air kg/m^2

C: heat capacity of air J/kg/K

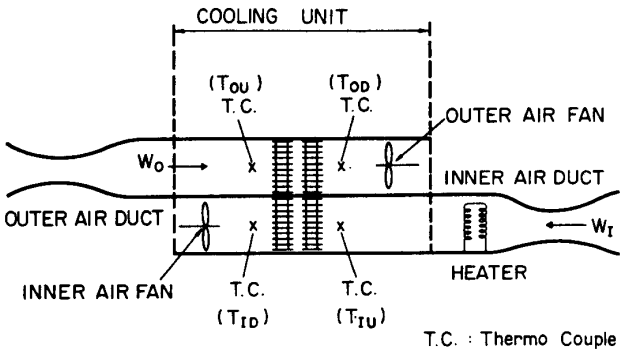

Fig. 5. Rough picture of Heat test of cooling unit only.

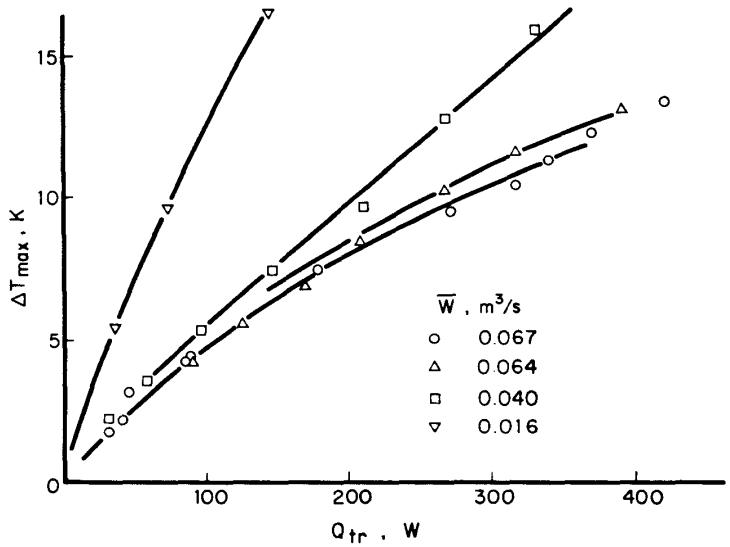

Fig. 6. Heat test of cooling unit only.

Wi:	volume flow rate of inner air	m^3/s
Wo:	volume flow rate of outer air	m^3/s
Tiu:	temperature of inner upward flow	K
Tid:	temperature of inner downward flow	K
Tou:	temperature of outer upward flow	K
Tod:	temperature of outer downward flow	K

Fig-6 shows these results. The vertical axis indicates

$$DT_{max}=Tiu-Tou \tag{2}$$

and holizontal axis indicates Otr (W). The parameter, the mean volume flow rate, defined as following.

$$W=0.5(Wi+Wo) \tag{3}$$

The linear zone of these plots is equivalent to the linear zone of Fig-3.

The effects of the air flow rates are shown in Fig-7. The vertical axis indicates the imaginary heat conductance through the cooling unit

$$C'=Qtr/DT_{max} \tag{4}$$

and the holizontalzxis indicates 0.8 times of the mean air velocity at heat-pipe heat exchangers

$$U=W/S \tag{5}$$

S: cross section area of air duct at heat-pipes m^3

Two groups of experiment data, $DT_{max}=10$K and $DT_{max}=5$K, are plotted in Fig-7. Two lines in Fig-7 indicate the regression lines which are obtained from two group of plots in Fig-7. They are

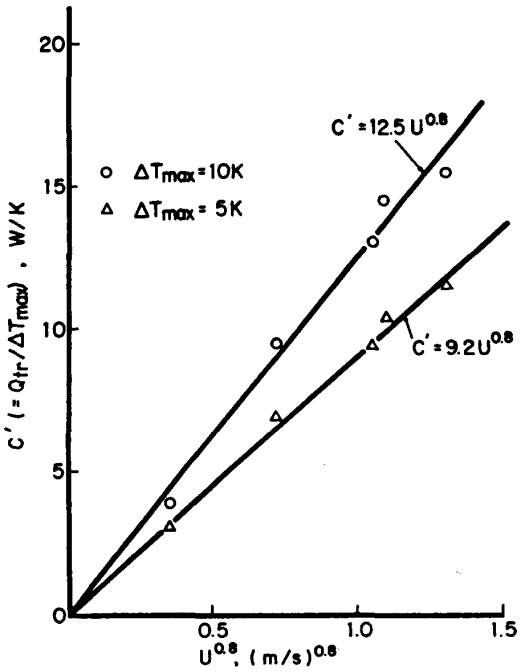

Fig. 7. Velocity effect for cooling unit.

$$C'=KU^{0.8} \tag{6}$$

$$K=\begin{cases}12.5 & \text{at } DT_{\max}=10\text{ K} \\ 9.2 & \text{at } DT_{\max}=5\text{ K}\end{cases}$$

In this region, where $DT_{\max}$ is greater than 5 K, it can be said that the heat transport capability of thc cooling unit is decided only by the air flow rates.

5. The Thermal Test of the Cooling Unit on the Closed Box

One of the results of the thermal tests of the cooling unit on the top of the closed box, like Fig-2, is shown in Fig-8. The vertical axis indicates the temperature difference from the outer air temperature, and the holizontal axis indicates the position in the stream line.

The heat load in the closed box is 580 W which is the target value. Because the height of the closed box is nearly 2 m, the heat loss from the wall of it is great, almost 250 W. So, the heat amount transfered through the cooling unit is about 450 W.

The temperature change of the outer air is 3.4 K, and that of the inner air side is 5.0 K. These results show that the flow rate of the inner air decreases by the flow resistances in the closed box. The maximum temperature difference is 12.8 K, so the target spec is almost atained.

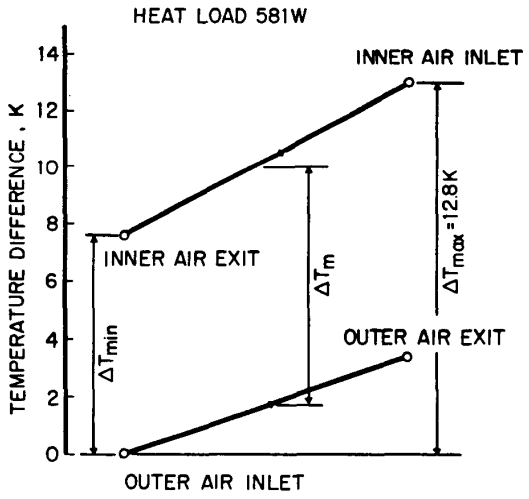

Fig. 8. Heat test of cooling test on closed box's top.

6. Conclusion

A cooling unit for a closed box is developped in order to protect electric equipment from bad atomosphere. The cooling unit has heat-pipe heat exchangers and a tandem-type scirocco fan. The finned tubes for the heat-pipes have large heat transfer area and the scirocco fan has large flow rates and very low noise. So, the cooling unit also has high performance and make low noise. It is set on the top of the closed box and it has good construction for easy maintenance.