PERFORMANCE EVALUATION OF CONTROL PANEL HEAT EXCHANGER

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ABSTRACT

Due to miniaturization, weight reduction, and high density of electronic equipment, the control panel has become smaller and the internal heat generation temperature is higher. In addition, the installation place of the control panel is a factory etc., heat, dust, moisture, oil mist adversely affect the electronic control unit. Therefore, a control panel heat exchanger is used for sealing the control panel and releasing the heat generated therein to the outside. We evaluated the performance of the control panel heat exchanger in this research.

Experiments shall be conducted in accordance with the capacity evaluation test method of the Japan Thermal Solution Equipment for Cabinet Technical Association. Experiments were conducted by installing a heat exchanger in the measurement reference box of 1700 mm in length, 700 mm in width, and 700 mm in depth made of a steel plate to which a heat insulating material with a thickness of 40 mm was attached. The dimensions of the heat exchanger are 900 mm in length, 438 mm in width and 129 mm in depth, and two fans are mounted on the inside of the heat exchanger and two on the outside air side. Twelve thermocouples were installed in the heat exchanger and twelve thermocouples were installed to check the temperature inside the box and the temperature was measured. An experiment was conducted until the temperature inside the panel reached a steady state by setting the heater unit in the measurement reference box and changing the calorific value. Experiments were also conducted until the temperature inside the board reached a steady state by changing the calorific value of the heater unit without operating the heat exchanger, and the heat release amount P_0 to the outside of the reference box for measurement was obtained. The calorific value P at the temperature difference of 20 K between the average value of the intake port temperature and the exhaust port temperature inside the panel of the control panel heat exchanger and the outside air temperature was obtained. The heat release amount P_0 is subtracted from the calorific value P and the value divided by the temperature difference 20 K is defined as the rated capacity of the control panel heat exchanger.

From the experimental results the rated capacity was 56.0 W/K.

INTRODUCTION

Due to miniaturization, weight reduction, and high density of electronic equipment, the control panel has become smaller and the internal heat generation temperature is higher [1]. However, in electronic devices, chemical reactions are promptly promoted at high temperatures, which greatly accelerates the failure rate and shortens the lifetime of electronic components. Also, the installation place of the control panel is a factory and so on, you must be careful not only for heat, but also for dust, moisture and oil mist. Since various parts of the control panel are made of metal, if the relative humidity exceeds 60%, corrosion progresses and there is a possibility that operation of the control panel may be hindered. In view of this, a control panel heat exchanger is used to discharge the heat generated inside while the control panel is hermetically sealed.

When using the control panel heat exchanger, it is important to have sufficient capability to cool electric devices in the control box. In the case of a heat exchanger having a high cooling capacity, the cost of the heat exchanger becomes high because unnecessary electric power is consumed. On the other hand, if the capacity is insufficient, it causes a failure of the electric devices because the devices in the control box cannot be sufficiently cooled.

Therefore, in this research, we conducted an experiment to evaluate the performance of the heat exchanger.

EXPERIMETAL APPARATUS

We have conducted an experiment in accordance with the capacity evaluation test method of the Japan Thermal Solution Equipment for Cabinet Technical Association [2].

Figure 1 shows a schematic diagram of the experimental apparatus. The experimental apparatus consists of a measurement reference box, a heater unit, a heat shield plate, and a heat exchanger. The dimension of the measurement reference box is 1700 mm in height, 700 mm in width and 700 mm in depth, and is made of a steel plate. In order to prevent heat release from the box, heat insulation material with a thickness of 40 mm is attached to each steel plate inside. The heater unit uses a coil heater, and five 700 W heaters are used. A heat shield plate was installed on the heater unit to eliminate the influence of radiant heat. For the heat shield plate, a flat plate punching metal having a thickness of 1 mm, a length of 500 mm, and a width of 500 mm was used. The hole diameter of the flat plate punching metal is 3 mm, and the pitch is 5 mm. Figure 2 and 3 shows the heat exchanger used in this experiment. The heat exchanger shown in Figure 2 is referred to as a heat exchanger 1. Further, the heat exchanger shown in Figure 3 is referred to as a heat exchanger 2. The dimension of the heat exchanger 1 is 900 mm in height, 438 mm in width and 129 mm in depth. Two fans are attached inside the box of the heat exchanger, and two are attached to the outside of the box. The dimension of the fan is 150 mm in height, 172 mm in width and 51 mm in depth. On the other hand, the dimension of the heat exchanger 2 is 525 mm in height, 236mm in width, 125 mm in depth. One fan is attached inside the box of the heat exchanger, and one is attached to the outside of the box. The dimension of the fan is 175 mm in height, 150 mm in width and 38 mm in depth. Twelve K-type sheath thermocouples (class 1) were installed in the heat exchanger, and the air temperature was measured. We also installed twelve K-type sheath thermocouples (class 1) to check the air temperature inside the box. The temperature measurement error was within ± 1.5 K.

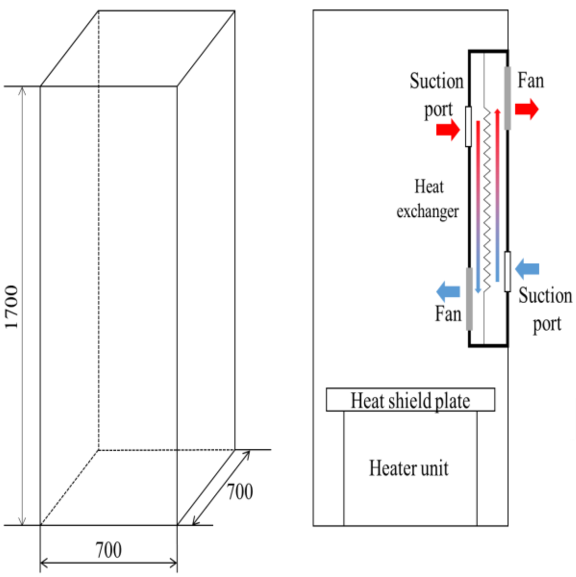

Figure 1 Schematic drawing of experimental apparatus

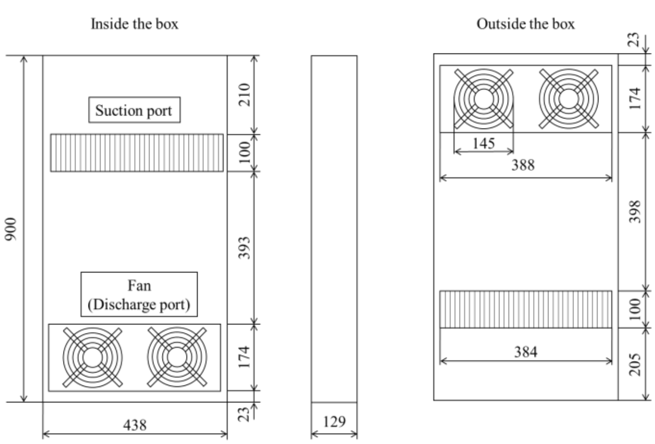

Figure 1 Schematic drawing of control panel heat exchanger 1

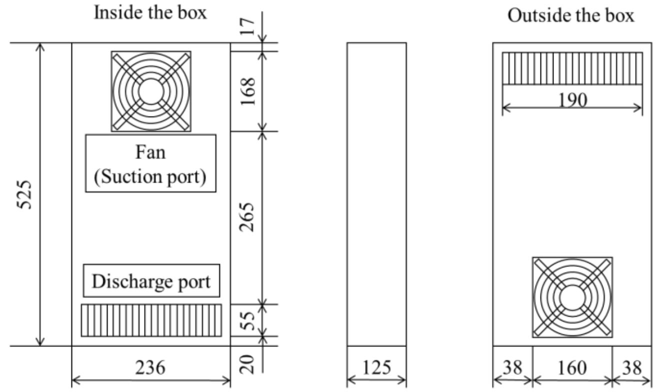

Figure 3 Schematic drawing of control panel heat exchanger 2

EXPERIMENTAL METHOD

An experiment was conducted until the temperature inside the box reached a steady state by setting the heater unit in the measurement reference box and changing the calorific value. Experiments were also conducted until the temperature inside the box reached a steady state by changing the calorific value of the heater unit without operating the heat exchanger, and the heat radiation amount P_0 to the outside of the reference box for measurement was obtained. The heater calorific value is P, and a value obtained by subtracting the heat radiation amount P_0 from the heater calorific value P is taken as the cooling capacity of the heat exchanger. Also, the difference between the average value of the suction port temperature and the discharge port temperature inside the box of the control panel heat exchanger and the outside air temperature is defined as the temperature difference ΔT and is shown as follows:

$$T_{hm} = \frac{T_{hi} + T_{ho}}{2} \tag{1}$$

$$\Delta T = T_{hm} - T_0 \tag{2}$$

In here, T_{hm}:: average temperature of suction port temperature and discharge port temperature inside panel of control panel heat exchanger [K], T_{hi}: average air temperature of suction port inside panel [K], T_{ho}: average air temperature of the discharge port inside the panel [K], ΔT: the difference between the average value of the suction port temperature and the discharge port temperature inside the panel of the control panel heat exchanger and the outside air temperature [K], T_o: outside air temperature [K].

When the temperature difference is 20 K, the value obtained by dividing the cooling capacity by the temperature difference is defined as the rated capacity Q of the control panel heat exchanger and is shown as follows:

$$Q = (P - P_0) / \Delta T \tag{3}$$

In here, Q: rated capacity [W/K], P: heater calorific value [W], P_0: heat radiation from the box when not operating the heat exchanger [W].

RESULTS AND DISCUSSIONS

Heat dissipation test

Figures 4 and 5 show heater calorific value per temperature difference. Heat exchanger 1 and 2 were measured for heat radiation without operating the heat exchanger. A linear approximation was obtained from the result, and it became as follows:

$$P_{0h1} = 3.88\Delta T \qquad (4)$$

$$P_{0h2} = 3.78\Delta T \qquad (5)$$

When comparing the heat exchangers 1 and 2, the heat radiation amount of the heat exchanger 1 increased more than 2. In order to install the heat exchanger used in the experiment in the box, the heat insulating material of the part where the heat exchanger is installed must be removed. Since the heat exchanger 1 is larger than 2, more insulation material has to be removed than 2. Therefore, it is considered that the heat radiation amount of the heat exchanger 1 has increased more than 2.

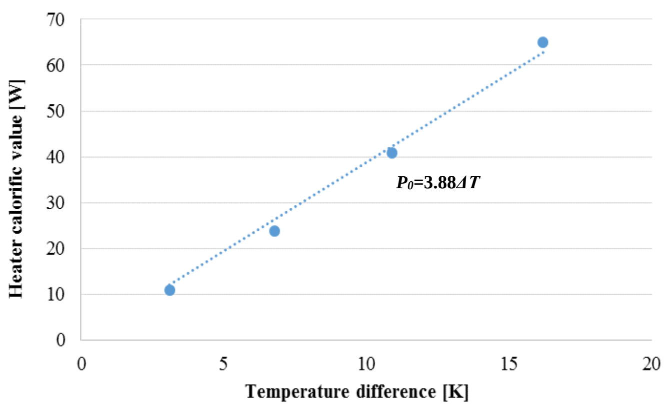

Figure 4 Heater calorific value per temperature difference of the heat exchanger 1

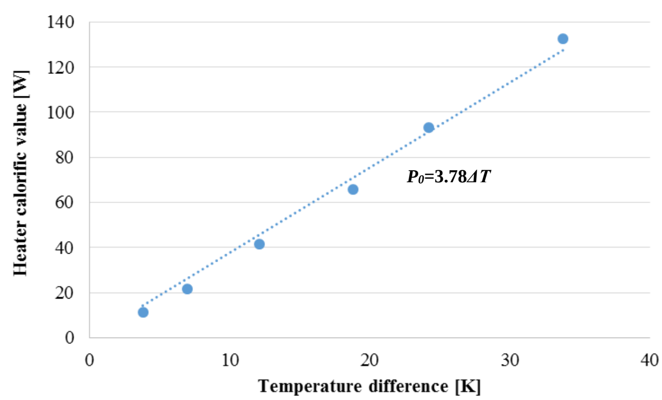

Figure 5 Heater calorific value per temperature difference of the heat exchanger 2

Cooling capacity

Figure 6 shows the cooling capacity of each heat exchanger. Table 1 also shows the temperature difference ΔT, heater calorific value P, heat radiation amount P_0, cooling capacity of each heat exchanger. The heat radiation amount P_0 was calculated by substituting it into the approximate expression obtained by the heat dissipation test. After calculating the linear approximation of cooling capacity from experimental results, it became as follows:

$$Cooling\ capacity_{h1} = 56.0\Delta T \qquad (6)$$

$$Cooling\ capacity_{h2} = 14.9\Delta T \qquad (7)$$

From this approximate expression, when calculating the cooling capacity at the temperature difference of 20 K between the heat exchangers 1 and 2, the heat exchanger 1 was 1120 W and the heat exchanger 2 was 298 W. Therefore, the rated capacity of the heat exchanger 1 was 56.0 W / K, and the rated capacity of the heat exchanger 2 was 14.9 W / K. Also, the control panel heat exchanger is used in a control panel whose temperature rise in the panel is about 10 to 20 K. Therefore, in the heat exchanger 1, it can be used for a control panel which generates heat of about 560 to 1120 W, and in the heat exchanger 2 it can be used for a control board which generates about 150 to 300 W of heat.

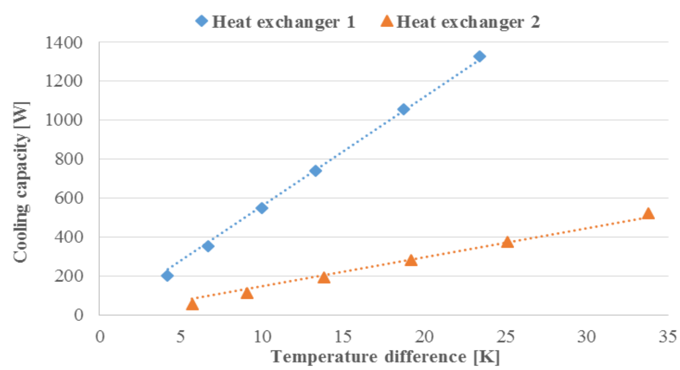

Figure 6 Cooling capacity of each heat exchanger

Table 1 Temperature difference ΔT, heater calorific value P, heat radiation amount P_0, cooling capacity of each heat exchanger

Heat exchanger	Temperature difference ΔT [K]	Heater calorific value P [W]	Heat radiation amount P_0 [W]	Cooling capacity [W]
1	4.2	218.0	16.3	201.7
	6.7	376.5	26.0	350.5
	10.0	586.2	38.8	547.4
	13.3	791.1	51.6	739.5
	18.7	1128	72.6	1055.4
	23.4	1417	90.8	1326.2
2	5.7	77.7	21.5	56.2
	9.1	148.7	34.4	114.3
	13.8	244.8	52.2	192.6
	19.2	352.6	72.6	280.0
	25.1	486.6	94.9	373.7
	33.8	649.7	127.8	521.9

CONCLUSION

Experiments were conducted by installing a heat exchanger in the measurement reference box of 1700 mm in height, 700 mm in width, and 700 mm in depth made of a steel plate to which a heat insulating material with a thickness of 40 mm was attached. Results are concluded as follows.

(1) When linear approximation of the heat radiation amount of the heat exchangers 1 and 2 was obtained without operating the heat exchanger, it became $P_{0h1} = 3.88\Delta T$, $P_{0h2} = 3.78\Delta T$.
(2) The rated capacity of the heat exchanger 1 was 56.0 W / K, and the rated capacity of the heat exchanger 2 was 14.9 W / K.

REFERENCES

[1] Masaru Ishizuka, 2009, Introduction to illustration Thermal design of well-known electronic equipment, Syuwa system, Tokyo, Japan.
[2] Thermal Solution Equipment for Cabinet Technical Association, 2003, Capability evaluation test method for control panel heat exchanger, Japan.