KOBEHONETSU™ Heat Releasing Steel Sheet

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High performance electronics equipment, especially with high-speed microprocessors, generates a large amount of heat. In order to release the heat efficiently from the heat source, Kobe Steel has developed a new steel sheet called KOBEHONETSU. The product is characterized by a unique thermal radiation mechanism which can release approximately seven times more heat than conventional electro-galvanized steel and reduces inside temperatures of the electronics equipment cabinets.

Introduction

Recent advances in electronic equipment have been realized by the progresses in a variety of technologies including speeding-up of the microprocessors, down-sizing of components such as resistors and capacitors, and high-density packaging of printed circuit boards.

High-speed microprocessors increase power consumption and associated heat generation. In addition, down-sized components, which are more densely packed on the printed circuit board, increase heat generation per unit volume. The increased heat disturbs the normal performance of the silicon chips and shortens the lives of other components.

Various heat release measures are applied to resolve the problem. Heat release measures, in general, are ways of efficiently transferring heat from the higher temperature interior to the lower temperature exterior of electronic equipment by exploiting heat-transfer mechanisms of thermal conduction, convection and radiation. As shown in **Table 1**, the conventional measures tend to use thermal conduction and convection. However, the heat transfer through apertures is accompanied by weakening of air-tightness and of electro-magnetic shielding. On the other hand, the use of cooling fans, heat-sinks and cabinet materials with higher thermal conductivity, tend to result in higher energy consumption, more number of parts and increased costs.

We have developed a unique, heat-releasing, steel sheet focusing on the thermal radiation which has received less attention in cooling technology. The newly developed product called "KOBEHONETSU"("honetsu" means heat-radiation) has more than 7 times higher heat releasing capability compared to electrogalvanized steel sheets, which have been used in general. This article describes the features and applications of KOBEHONETSU.

Table 1 Examples of conventional heat release measures

Heat release measures		Applied heat transfer mechanism
Structural design	Ventilation slots	Convection
Radiator	Cooling fan	Convection
	Heat sink	Conduction
	Heat pipe	Conduction
	Thermally conductive sheet	Conduction
Cabinet material	Thermally conductive materials	Conduction

1. Thermal radiation

Heat transfers by thermal conduction and convection are phenomena governed mainly by temperature differences and are not affected by the level of temperatures. On the other hand, thermal radiation, although still affected by temperature difference, becomes larger in its efficiency at elevated temperatures.[1)] Because of this, the heat release by radiation is less utilized in general electronic equipment in which the operating temperatures lie in the range of room temperature to 100 ℃.

The amount of heat transferred by radiation is calculated based on the semi-cylindrical model as shown in **Figure 1** where the heat source, cabinet and outer environment are placed in sequence from inside.[1)] The outer surface of the cabinet is denoted by the suffix 1, and the surface of the outer space is denoted by the suffix 2. The areas are

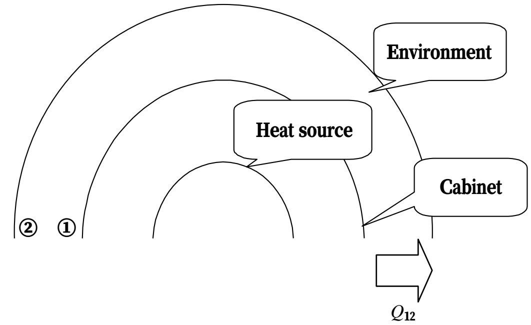

Fig. 1 Calculation model for thermal radiation transfer

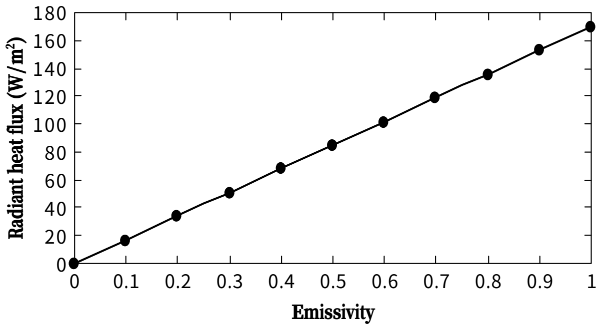

Fig. 2 Dependence of radiant heat flux on emissivity

denoted by A_1 (m^2) and A_2 (m^2) and emissivities are ε_1 and ε_2 respectively. Ignoring the heat transfer due to conduction and convection, the amount of heat radiated from the cabinet to the outside Q_{12} (W) is calculated as,

$$Q_{12}/A_1 = \varepsilon_1 \sigma \left(T_1^4 - T_2^4\right) \quad \cdots\cdots\cdots\cdots \quad (1)$$

where $\sigma = 5.67 \times 10^{-8}$ (W/m^2 • K^4) is the Stefan-Boltzmann constant, and T denotes temperature in Kelvin. The outer space is assumed to be infinite, or $A_2 = \infty$. Equation (1) indicates that the larger the emissivity of cabinet, the more amount of heat is transferred.

Radiation is heat transfer caused by the emission and absorption of electromagnetic waves with wave lengths of visible to far-infrared. Generally, metals reflect most of the electromagnetic waves in this wave length range and have low emissivity. The emissivity of a non-oxidized metallic surface is usually 0.1 or less.

Figure 2 shows a result of calculations based on equation (1) assuming the cabinet temperature of 50℃ and outside temperature of 25℃. Replacement of a cabinet having emissivity of 0.1 with the one having emissivity of 0.8 will increase the radiant heat flux by approx. 7 times. KOBEHONETSU described here is a steel product developed based on the above concept. Its high emissivity lowers the internal temperature of cabinets by a simple replacement of the cabinet material.

2. KOBEHONETSU

Heat radiation occurs through several processes: when electron transits from high energy states to lower states; in atomic vibration of molecules; and in lattice vibration of crystals.[2)] Accordingly, the lower energy state of each kinetic mode described above absorbs electromagnetic wave corresponding the energy difference between the energy states. This means that a treatment which increases the emissivity of steel-sheet surface will also work to absorb the radiated energy at the same time.

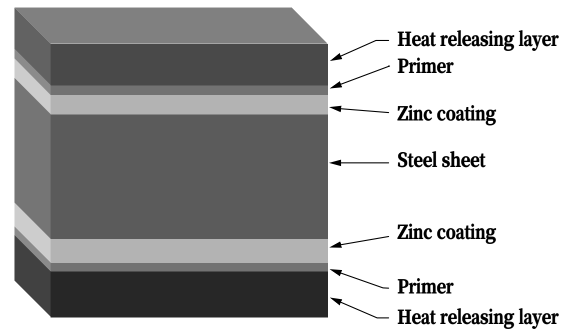

Fig. 3 Coating structure of KOBEHONETSU

KOBEHONETSU, when used for cabinets, exploits this radiation/absorption property and is designed in such a way that the internal surface absorbs heat from inside the cabinet and releases it to the outside through the steel-sheet and the external surface.

Figure 3 shows the layer structure of the KOBEHONETSU. The steel sheet is galvanized first for corrosion resistance. The heat-releasing layer is coated on the outermost surface after the application of primer which improves adhesion between the galvanized and heat-releasing layers. The heat-releasing layers are applied to both the surfaces of the sheet so that heat is absorbed from inside and released outside efficiently. The emissivity of the heat releasing layer is 0.86 on both surfaces and this corresponds to an emissivity approx. 7 times higher than that of the conventional finger-print resistant, galvanized steel sheet.[1)]

3. Heat releasing performance of KOBEHONETSU

The heat releasing performances of KOBEHONETSU were evaluated by two kinds of experiments, in one of which KOBEHONETSU is used as a part of a cabinet, and in another of which it is used as a radiator.

A cabinet as shown in **Figure 4** was prepared and the inside temperature T_1 was measured.[1)] **Figure 5** shows the rise of the inside temperature T_1 for KOBEHONETSU and for a conventional finger-print resistant, electro-galvanized steel, both used as the top-cover samples. In this experiment, heat (15 W) from the source is transferred to the steel sheet surface by radiation and convection, and is released from the outer surface by radiation and convection. The temperature T_1 after 100 minutes of heating is lower by approx. 8℃ when the KOBEHONETSU is used.

Photo 1 and **Figure 6** show an experimental

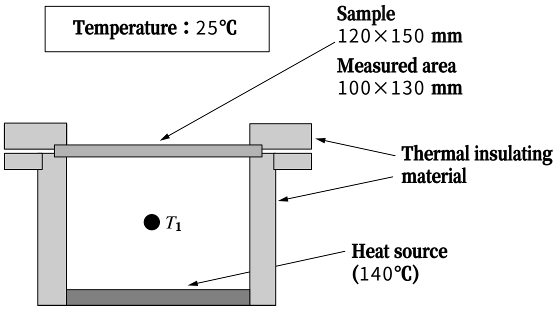

Fig. 4 Evaluation method of heat releasing properties

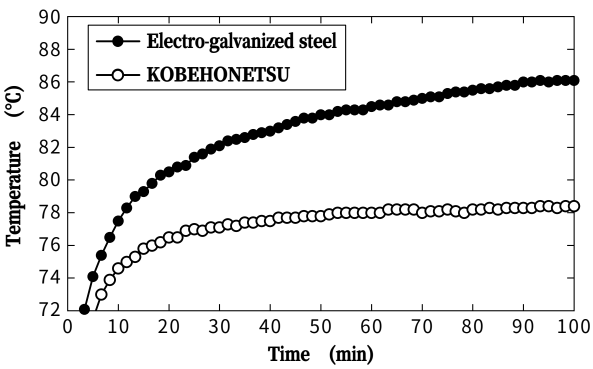

Fig. 5 Heat releasing behavior of KOBEHONETSU

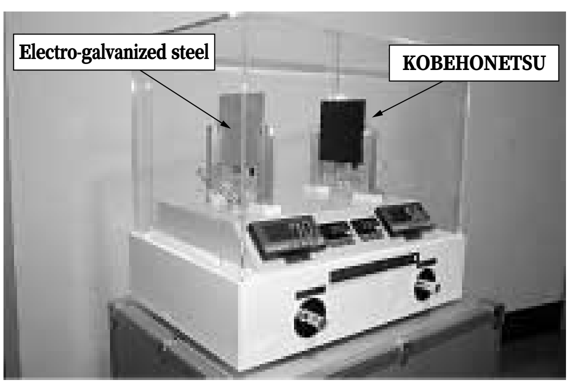

Photo 1 Method to evaluate performance of KOBEHONETSU as a radiator plate

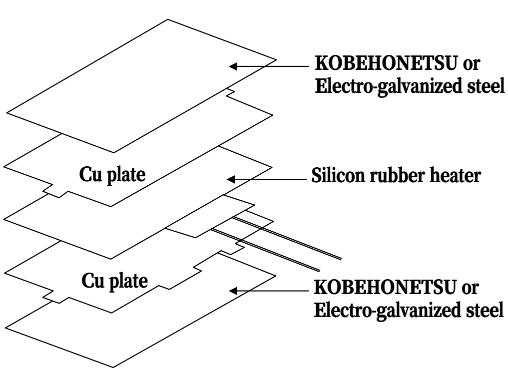

Fig. 6 Structure of radiator plate

model in which samples were used as radiators. A constant heat input of 9.2 W was applied to both the samples. In this experiment the heat is transferred from the heat source to the steel sheet surface by conduction and released from the sheet surface by radiation and convection. The surface temperature of KOBEHONETSU radiator was lower by as much as 14℃, indicating that the components directly attached to the cabinet can be cooled efficiently.

4. Properties

Various other properties are required for the practical use of steels in cabinets and radiators. The following describes various practical properties of KOBEHONETSU other than its heat releasing capability.

4.1 Conductivity

The surface of KOBEHONETSU is electrically conductive and easy to ground through the cabinet. **Figure 7** shows the surface electric conductivity measured by the four-wire (Kelvin Sensing) method. The conductivity is in the range of 0.01 to 0.1 mΩ, and is comparable with conventional galvanized steel with finger print resistance and chromate treatments. The conductivity ensures the electromagnetic shielding at the seams of cabinets. **Figure 8** shows an example of electric shielding properties measured by the KEC method.[3] Generally, non-conductive surface coatings deteriorate the shielding

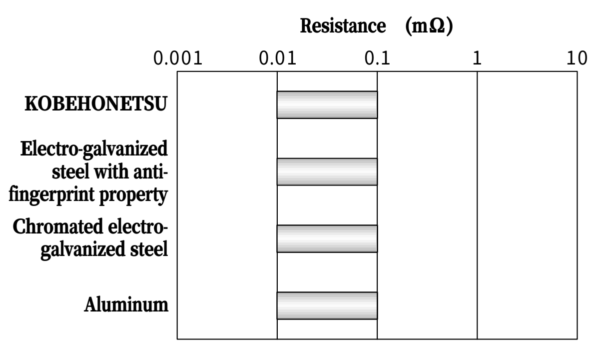

Fig. 7 Surface electric conductivity of KOBEHONETSU

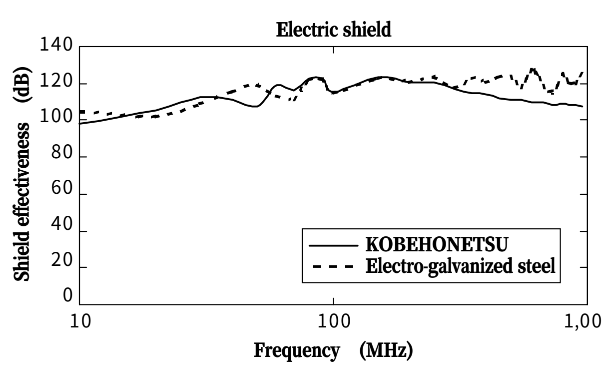

Fig. 8 Electric shield of KOBEHONETSU

properties. The KOBEHONETSU has shielding properties which are as good as generally-used galvanized steel with finger-print resistant coating, and satisfies both the shielding and heat-releasing capabilities required by electric equipment.

4.2 Workability

As indicated in **Table 2**, the sheet can be bent not only to a 90 degree angle but even to a complete fold depending on thickness. The sheet also has sufficient surface hardness. The press-formability is assured with good adhesion of the surface layers, high impact resistance and low dynamic friction. **Photo 2** shows an example of the sheet formed into an audio equipment part.[4]

4.3 Corrosion resistance

Figure 9 shows the result of a salt-spray test showing the relation between spray time and white rust ratio. The heat releasing layers provide higher corrosion resistance than the conventional electro-galvanized steel. No rusting occurred during the humidity cabinet test of 40℃×95% × 240 hrs, proving applicability of the sheet to electronics equipment.

Table 2 Mechanical properties of heat releasing layer

T-bend (no crack limit)	0T
Pencil hardness	H~2H
Cross-hatch Ericsen	100/100
DuPont impact	5/5
Coefficient of dynamic friction	0.086

Photo 2 Forming example of KOBEHONETSU

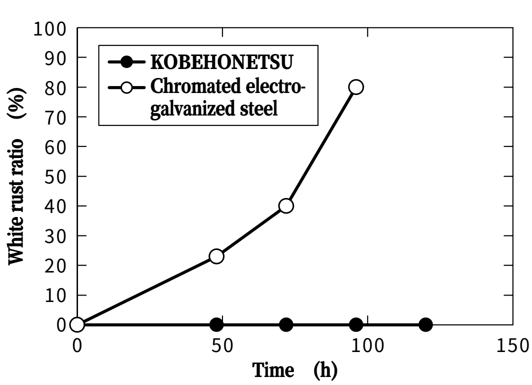

Fig. 9 Corrosion resistance of KOBEHONETSU

4.4 Environmental consideration

Neither the heat-releasing layer nor the primer layer contains chromate, ensuring lower environmental burden.

4.5 Designability

The standard color is matted black and can be used as an exterior panel. Surfaces with silver metallic color and white high-reflection color have also been developed.

5. Applications

We started development of KOBEHONESTU in 2001 and received acceptance a year later. Examples of actual applications so far include the top covers of DVD drives, hard-disk cabinet (**Photo 3**), hard-disk recorder cabinet (**Photo 4**) and cabinets for car navigation equipment. In many

Photo 3 Hard-disk cabinet

Photo 4 Hard-disk recorder cabinet

applications the cooling fans have been eliminated, which contributes to the reduction of cost, noise and energy consumption. Applications to the back-panel of FPD equipment such as liquid crystal displays (LCD) and plasma display panels (PDP) are also being considered.

Conclusions

Internal temperatures of electronics equipment cabinets are becoming higher and, it is said, are approaching the limit for recording media, and affecting the lives of precision parts. KOBEHONETSU provides effective heat-releasing measures, especially when the alternative of heat-releasing by conduction leads to an increased number of parts and higher cost, or the heat-releasing by convection can not be used for reasons of air-tightness. KOBEHONETSU further improves equipment performance by allowing the use of higher capacity motors and more stacks of circuits. Conversely, it can reduce the size of cooling fans and radiator fins, or completely eliminate them, and thus contribute to the reduction of cost. KOBEHONETSU is a useful material in the speed-up, downsizing, energy saving and noise reduction of high performance equipment.

References

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3) *A method to evaluate shielding effectiveness* developed by Kansai Electronic Industry Development Center (http://www.kec.jp/menu2/6.htm).
4) Y. Hirano, et al., *R&D Kobe Steel Engineering Reports*, Vol.52, No.2, p.107 (2002).