Drink Showcase Equipped with Inverter Freezer

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ABSTRACT

In recent years, the impact of earthquakes has increased the demand for replacing products with more energy saving alternatives. Furthermore, convenience stores are also requiring open showcases that increase the product display area. Fuji Electric has developed an 8-shelf showcase that utilizes an inverter freezer and has a display area 1.57 times greater than previous products. The unit makes use of a new scroll compressor, while also adopting a new cooling system that utilizes segmented airflow, thus enabling the unit to achieve optimal inverter control that saves energy and stabilizes temperatures inside the showcase. We have also developed a mechanism that uses the evaporation fan to implement forced evaporation of drain water with the aim of saving energy and reducing the operation. The unit achieves a 67% reduction in power consumption per unit area.

1. Introduction

In recent years, the impact of earthquakes has raised the awareness of energy saving and increased the demand for replacing products with more energy-saving alternatives. In convenience stores, there is an increased demand for reduction of the operations for product display and cleaning in order to improve efficiency of store operations.

For meeting these market demands, Fuji Electric has developed an drink showcase equipped with inverter freezer. We are the first to achieve extensive energy savings with an 8-shelf drink showcase that has a display area 1.57 times greater than previous 6-shelf showcases.

2. Development Background

Convenience store customers have traditionally been mainly young people, but the customer base is expanding to include people living alone, the elderly and women in dual-income households. The expansion of the customer base and broadening of customer demands have led to the increase in the types of goods they offer. In addition, development of private-label products, which offer high profitability, is active in the convenience store industry and open showcases with increased product display areas are desired for efficiently displaying products in smaller store spaces than those of supermarkets. Furthermore, the advent of energy drinks – the market for which has rapidly grown in the last few years and is said reach a scale of 50 billion yen in FY2015 – has created a demand for increased display areas for nutritional drinks.

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3. Development Goals and Challenges

Figure 1 shows the newly developed drink showcase equipped with inverter freezer. The goals of development are improved product display efficiency by increasing the product storage capacity, energy saving by utilizing an inverter freezer, and reduction of the operation by completely evaporating drain water.

For increasing the product storage capacity, we have expanded the front opening by increasing the height and lowering the front edge of the base of the unit and increased the capacity and product display area in the showcase by increasing the number of shelves. Expanding the front opening causes a significant increase in energy consumption because of the increased amount of external air infiltration. To address this problem, we fundamentally revised the conventional air curtain and developed a new cooling system that also utilizes “segmented airflow” produced by making a duct structure to channel cold air

Fig.1 Drink showcase equipped with inverter freezer

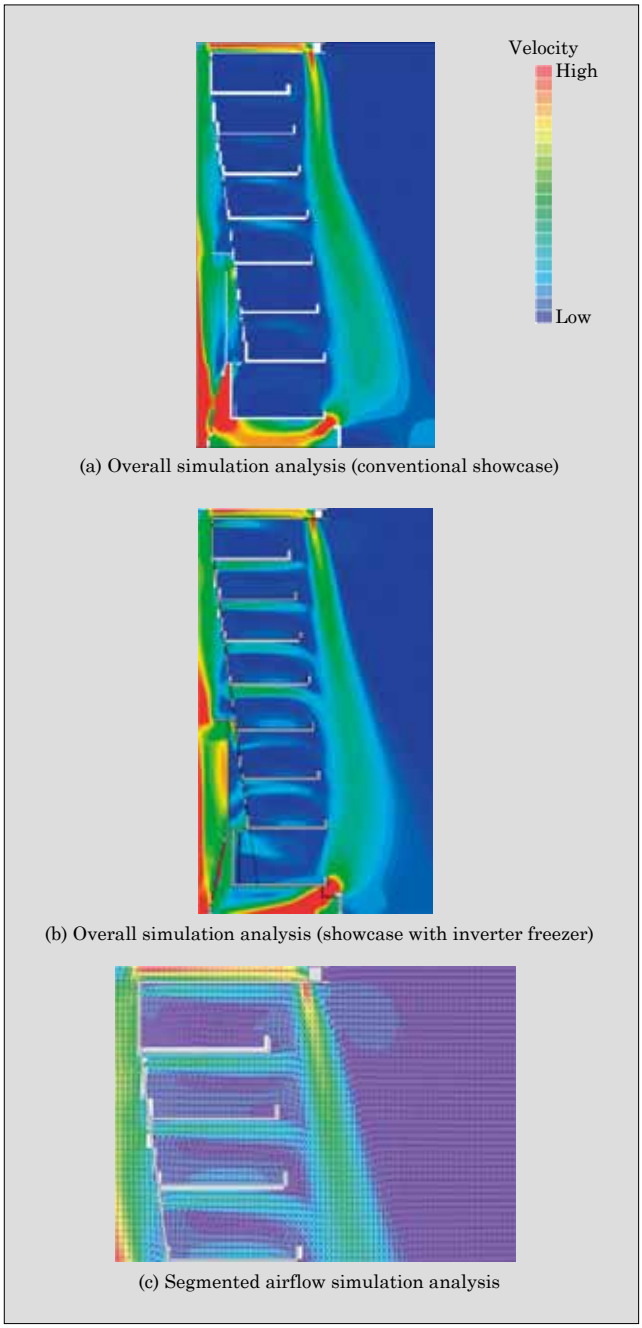
from the back to under the shelves. We also revised the conventional constant-speed operation of the installed freezer and developed an inverter-controlled system with a significant energy saving goal of reducing the amount of power consumption per unit capacity to a half or less. Another challenge was drain water. Conventionally, the drain water generated during defrosting was stored, which an employee had to drain out when the tank became full. With the aim of saving energy and reducing operation, we have worked to eliminate the evaporation heater from the drain water evaporation system and implement the ability to completely evaporate water without requiring a drain water tank.

4. Features

4.1 New cooling system

Figure 2 shows the result of flow velocity simulation analysis by using an optimization design support tool. In one common cooling system of conventional open showcases, the air curtain from the air outlet was used to shut off the external air and the cold air of the air curtain was drawn to individual shelves to use for cooling, which is supplemented by the air from the outlet on the back (see Fig. 2 (a)).

The newly developed system makes use of the cold air blowing from the back of a shelf, which is channeled through a duct made under the shelf above to allow even cooling of products. In this cooling system that utilizes segmented airflow, the cold air that flows under the shelves merges with the cold air of the air curtain. This reinforces the air curtain, allowing it to maintain a low temperature even near the lower shelves (see Fig. 2 (c)). Furthermore, an optimization design support tool has been used to extend the position of the canopy (cold air outlet projection at the top), adopt a honeycomb structure for the cold air outlet, and optimize the deck-integrated fence in front of the air inlet and air volume balance. This has achieved significant improvement in even temperature distribution in the showcase from 14 K to 7.1 K (see Fig. 2 (b)).



(a) Overall simulation analysis (conventional showcase)

(b) Overall simulation analysis (showcase with inverter freezer)

(c) Segmented airflow simulation analysis

Fig.2 Result of flow velocity simulation analysis by optimization design support tool

4.2 Inverter-controlled refrigeration system

Figure 3 shows the configuration of the freezer system, and Fig. 4 shows the structure of the freezer. Figure 5 shows the operation modes of the freezer.

The conventional constant-speed operation control of a freezer maintains the temperature in the showcase within a certain range by turning the freezer on and off, as shown in Fig. 5 (a). On-off switching occurs frequently and the inrush current that flows when the freezer is turned on increases the amount of power consumption. The on-off operation also causes hunting, or oscillation of the air temperature in the showcase, which increases the range of temperature distribution, making it difficult to stabilize the temperature.

To address this problem, we have adopted a new scroll compressor and developed optimal inverter control that saves energy and stabilizes temperatures inside the showcase, as shown in Fig. 5 (b). This control minimizes fluctuation of the temperature at the showcase air outlet detected with a temperature control sensor and allows to settle in the targeted air temperature promptly.

Specifically, when the temperature in the showcase rises abnormally, called pull down, during operations such as defrosting, the compressor operates at a constant high speed to rapidly lower the increased temperature in the showcase. When the temperature at the air outlet has reached the target, PID control is ap-

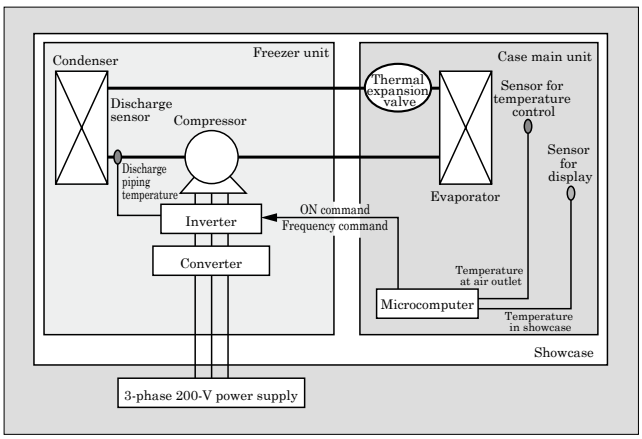


Fig.3 Feezer system configuration

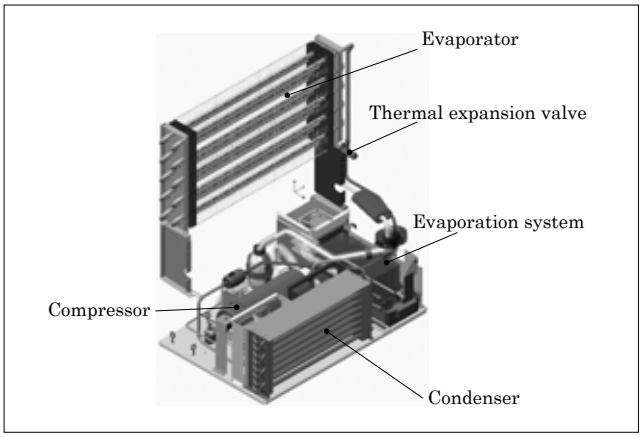


Fig.4 Freezer structure

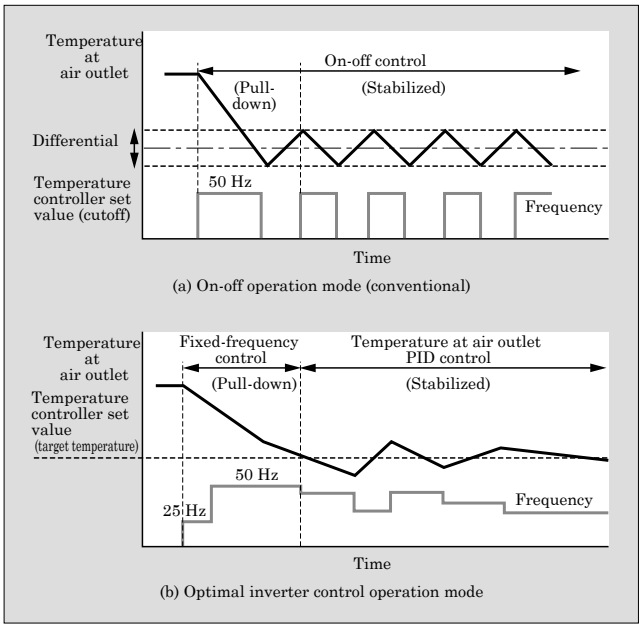


Fig.5 Freezer operation modes

plied to control the rotational speed of the compressor so that the temperature at the air outlet converges to the target temperature.

This inverter control has achieved a reduction of the amount of power consumption of the freezer from the conventional 16 kWh/d to 9.2 kWh/d, or by 42.5%, in operation under the conditions of 27 °C and 70%RH in the summertime. In addition, the amplitude of the temperature of the refrigerant discharge piping has decreased from the conventional 4 K to within 1 K, contributing to energy saving and stabilization of the temperature in the showcase.

4.3 Drain water evaporation system

Even though drink showcases are shielded with air curtains, they take in external air while cooling, which generates a large amount of drain water. Figure 6 shows the drain water evaporation system. Conventional showcases had primary and secondary evaporating dishes. The primary evaporating dish uses the heat of the evaporator coil on the cooling unit to achieve evaporation. The secondary evaporating dish uses an exclusive evaporation heater and a drain tank. This causes the heater to consume 6.9 kWh/d of electric power. With the newly developed showcase, the heater was eliminated for saving energy and the drain tank was also eliminated to reduce water draining operation by an employee. The goal was to achieve complete evaporation under the conditions of 27 °C and 70%RH in the summertime using forced evaporation by means of the evaporation fan.

(1) Structure of the evaporation system

The amount of evaporation is proportional to the air volume and the surface area of evaporation, and is also greatly influenced by the temperature (see Fig. 7).

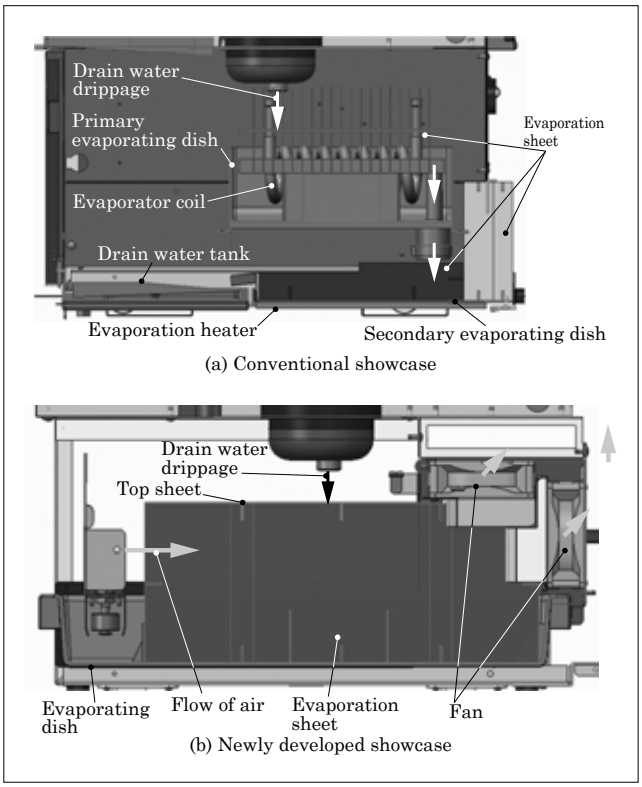


Fig.6 Drain water evaporation system

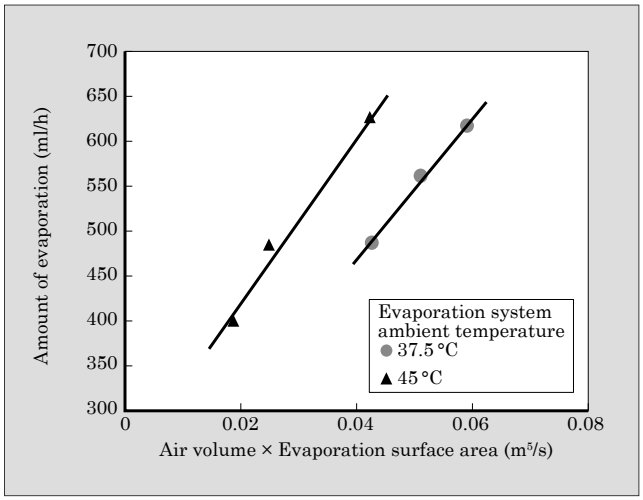


Fig.7 Amount of evaporation vs. air volume, evaporation surface area and temperature (experimental results)

Placing evaporation sheets on the fan air outlet side increases the effective air volume and in turn the amount of evaporation. However, in order to make it possible to remove the evaporating dish and exhaust the evaporated moist air by the heat of the cooling unit from the evaporation system to the back of the drink showcase, we have placed the fans behind the evaporation sheets as shown in Fig. 6 (b).

To increase the volume of air that passes through the evaporation sheet within a limited space, we have used 2 fans and determined the optimum arrangement of the evaporation sheets and fans by using airflow analysis (see Fig. 8).

(2) Improvement of evaporation capacity of evaporation sheets

With the conventional evaporation sheets, the water collected in a dish was simply absorbed by a vertically stretched evaporation sheet, which left the upper part of the sheet dry, and evaporation capacity was not being fully utilized. To address this problem, a top sheet has been added as shown in Fig. 6 (b) so that the drain water drippage spreads across from this top sheet, which is horizontally stretched. This has made the side and top sheets form a duct structure, which successfully allows the fan air to be carried through the entire span of the sheets. In addition, the water

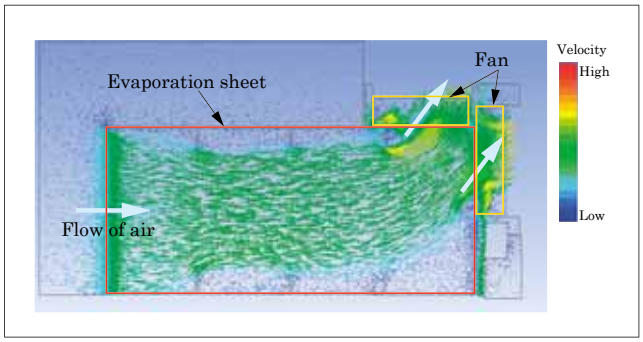


Fig.8 Airflow analysis result

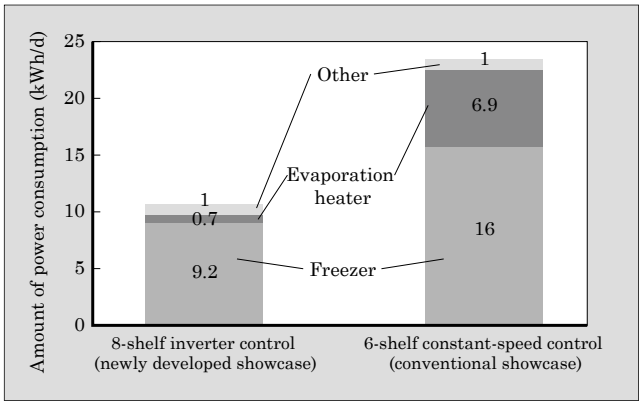


Fig.9 Comparison of amount of power consumption

Table 1 Performance comparison

Item	8-shelf inverter control (newly developed showcase)	6-shelf constant-speed control (conventional showcase)
Showcase capacity (L)	240	175
Average air temperature (°C)	7.6	9.3
Amount of power consumption (kWh/d)	10.9	23.9
Amount of power consumption per unit capacity (kWh/d/L)	0.045	0.137
Display area (m²)	1.57	1.00

retention effect of the top sheet and the effect of the duct structure have improved evaporation efficiency by 80%.

The improved evaporation capacity of the evaporation sheets has made complete evaporation without a heater, and the amount of power consumption has been reduced by approximately 90% from 6.9 kWh/d with conventional showcases to 0.7 kWh/d.

4.4 Performance

By making use of the new technologies described above, we have achieved a significant reduction in the amount of power consumption per unit capacity of 67%, which exceeds the goal of 50%. Figure 9 shows a comparison of the amount of power consumption with conventional showcases, and Table 1 shows a comparison of performance.

5. Postscript

This paper described the drink showcase equipped with inverter freezer. This newly developed product has been highly rated by customers for its improved product display efficiency, energy saving and reduced operations. However, the demands of the convenience store industry are rapidly changing by the moment. We will continue to actively promote the development of new products that anticipate the needs of the market and lead the industry.