# “Frozen Station” Frozen Food Vending Machine

FUKUDA, Katsuhiko* IWAKO, Tsutomu* NAKANISHI, Toshikazu*

**ABSTRACT**

The market for home meal replacements has been growing rapidly due to changes in lifestyles, and in particular, frozen foods are increasingly in demand for their improved flavor provided by freezing technology advancement and as promising means of solving the problem of food loss. Fuji Electric has developed the“ Frozen Station” frozen food vending machine, which can sell products in stores at various locations 24 hours a day without face-to-face interaction. While achieving the industry’s largest storage capacity capable of stocking 70 large-sized products, the storage structure and conveyance technology for various forms of frozen products stabilize the posture of the products by controlling the posture during dropping. In addition, by optimizing the shape of the conveyance chute, the conveyance resistance is reduced, enabling stable conveyance of goods.



## 1. Introduction

The impact of COVID-19 has changed lifestyles and increased the demand for ready-to-eat meals. In particular, domestic factory shipments of frozen foods for household use reached a record high in 2021.(1) The frozen food market is expected to grow 8.37% annually until 2030. The reason for this is that consumers are attracted to frozen foods because of their deliciousness achieved through improvements in freezing technology, as well as their ability to reduce food loss and waste, contributing to one of the sustainable development goals (SDGs). Against this backdrop, there is a growing need for restaurants, which have played a key role in the food service industry, to sell dishes previously served in their restaurants in the form of frozen foods as a countermeasure against the decline in sales and shortened business hours caused by COVID-19 restrictions. In response to this change in consumer preferences, Fuji Electric has developed a vending machine that can sell frozen foods at various locations such as stores, 24 hours a day, without face-to-face interaction. In this paper, we will introduce the “Frozen Station” frozen food vending machine.

## 2. Challenges Facing Frozen Food Vending Machines for Restaurants

This newly developed frozen food vending machine is expected to be used by restaurants to sell frozen foods (dishes) as a new sales channel for the products they have conventionally offered in their stores. Since theses frozen foods will be prepared by the restaurants themselves, they will come in a wide variety of shapes, sizes, and weights. Furthermore, it is assumed that products will often be wrapped in a food pack shown in Fig. 1. Therefore, this new frozen food vending machine needed to have a storage structure and conveyance mechanism capable of handling a variety of products types. Moreover, it was important for the frozen food vending machine to be able to store as many products as possible at one time. This reduces the loss of sales opportunities due to sold-out products and decreases the frequency of product replenishment.

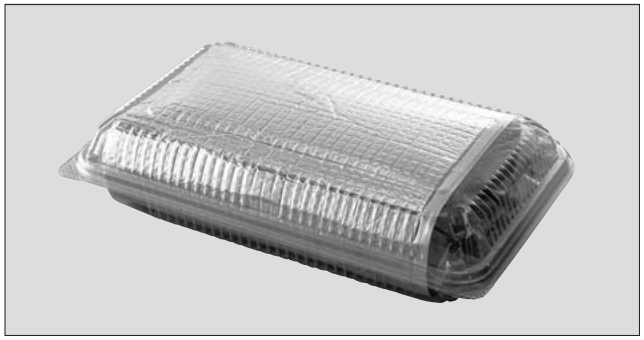

Fig.1 Food pack

It is also assumed that this frozen food vending machine will be operated directly by the restaurant that installed it. Another important issue is to ensure that the vending machine could be operated smoothly even by users who are not familiar with its operations.

## 3. Features of the “Frozen Station” Frozen Food Vending Machine

### 3.1 Overview

Figure 2 shows the appearance of the Frozen Station, and Table 1 lists its specifications. The dimensions of the Frozen Station are the same standard size as our ice cream vending machines. This allows it to

* Food & Beverage Distribution Business Group, Fuji Electric Co., Ltd.


Fig.2 “Frozen Station”

Table 1 “Frozen Station” specifications

| Item | Specification |
|---|---|
| Type name | FFS107WFXU1 |
| Dimensions | W1,161 × D836 × H1,830 (mm) |
| Type of sales | 7 selections with 10 selection buttons |
| Mass of products that can be stored | 500 g or less |
| Product mass | 330 kg |
| Lighting | LED |
| Installation environment | Installable indoors and outdoors |
| Product storage temperature | −23°C to −19°C |
| Power consumption | 2,500 kWh/y |

be installed in general locations while maintaining sufficient internal volume.

### 3.2 Storage structure for various products

In designing the storage structure, we first surveyed food packs and commercially available frozen foods, and determined that the product sizes should be able to accommodate a width of 150 to 230 mm, depth of 100 to 155 mm, and height of 41 to 51 mm. Table 2 shows the specifications.

Assuming the sale of large products such as pasta and ramen noodles, we designed the rack structure with an emphasis on efficient storage in order to ensure a sufficient number of product types and capacity. Figure 3 shows the rack structure of its vertical single

Table 2 Specification of products sold

| Item | Specification |
|---|---|
| Maximum capacity per column | 10 |
| Width | 150 to 230 mm |
| Depth | 100 to 155 mm |
| Height | 41 to 51 mm |
| Maximum diagonal length | 250 mm or less |
| Mass | Single rack total 4,000 g or less, 500 g or less per product |

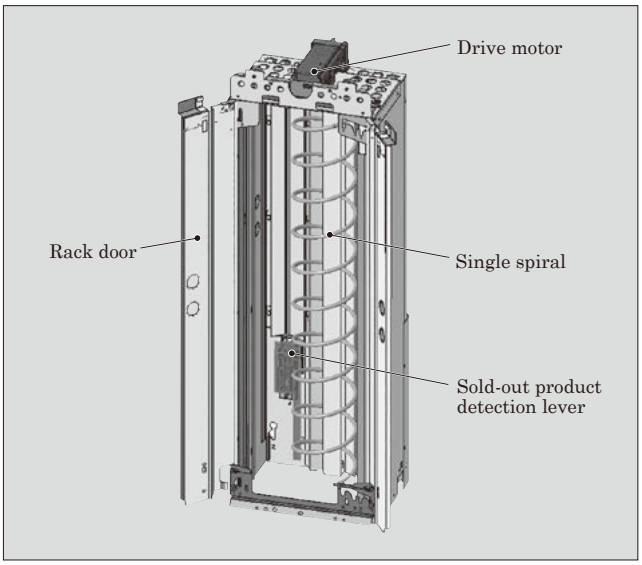


Fig.3 Rack structure of the vertical single spiral system

spiral system. As a system capable of efficiently storing large-sized frozen foods, based on a rack structure that has a proven track record in our ice cream vending machines, we placed a large-diameter spiral of 110 mm at the back of the racks to create a slim structure without spiral fixing parts on either side of the racks, delivering a capacity of 10 products in a rack.

Figure 4 shows the rack arrangement. By slimming down the rack in the width direction, we arranges four columns in the horizontal direction, giving a total of seven columns suitable for large products. This enabled it to achieve the industry’s largest storage capacity of 70 large-sized products, such as frozen pasta and side dishes.

We also provided it with movable partition plates (adjusters) that can adjust the rack width. This prevents products from falling out of a rack due to the variety of container sizes and types and also stabilizes conveyance for all product sizes. Figure 5 shows an example of the partition plate adjustment. To hold products of various sizes stably in the racks, operators can adjust the inner width of the racks in six levels according to the width of the products. It utilizes an ad-

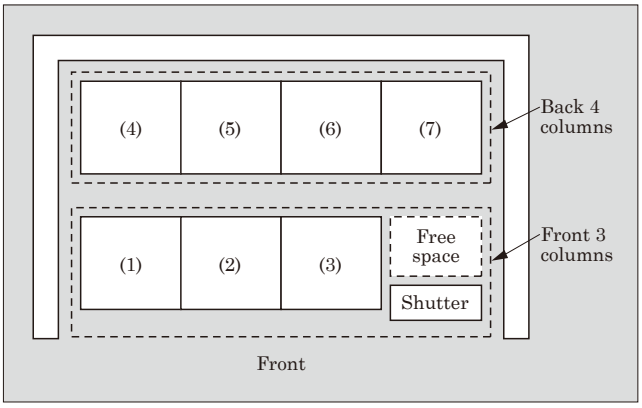


Fig.4 Rack arrangement (top view)

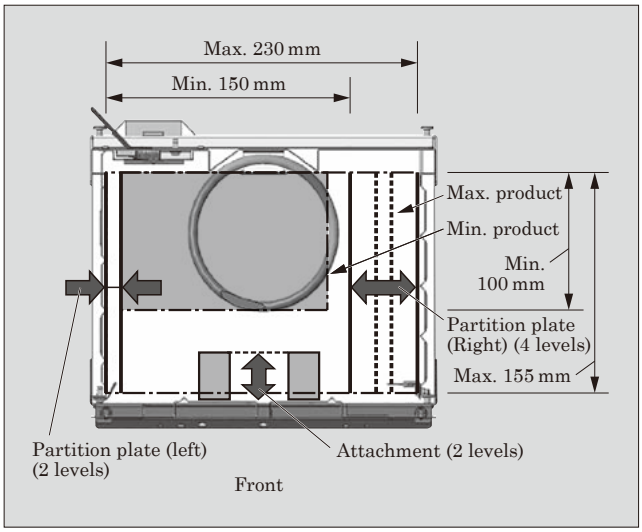


Fig.5 Example of the partition plate adjustment

juster structure that can be easily adjusted with a sliding motion that eliminates the need for troublesome operations such as reattaching the partition plate. To accommodate the depth of different products, it has a lightweight attachment that can be attached to or detached from the door side, allowing for two levels of adjustment. These features allow food packs of different dimensions to be stably stored.

In terms of product height, the Frozen Station comes standard with spirals that can accommodate products within the dimensional range specified in the specifications. To accommodate products with heights outside this range, spirals with spacing appropriate to the height of the products are available as an option.

This design contributes to the mechanism that can store products of various sizes.

### 3.3 Mechanisms to ensure the dispensing of products

(1) Spiral rack mechanism

As mentioned previously, the rack structure for storing products uses a vertical spiral system that facilitates product replenishment. In a vertical spiral system, the spiral of the conveyance unit rotates to push products downward. It is available as a single spiral system [see Fig. 6(a)] or a twin spiral system [see Fig. 6(b)]. In a twin spiral system, as shown in Fig. 6(b), both ends of the product are inserted into the left and right spirals to hold the product horizontally, making it easier to control the falling posture of the product when dispensing it. The use of two spirals however causes the rack width to be larger than that of the product. In a single spiral system, the rack width is reduced to enable products to be loaded diagonally along the spiral, and the storage efficiency can be increased relative to the floor level of the vending machine. In light of these features, we uses the single spiral system for the Frozen Station.

However, with this system, if the product is rectangular-shaped, it could fall upright in the longitudinal

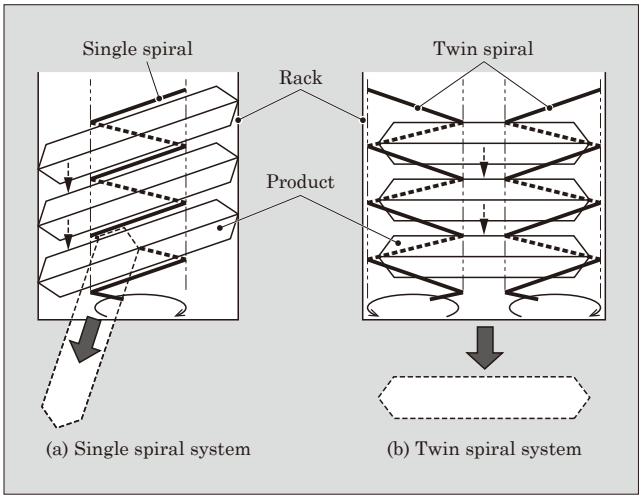


Fig.6 Rack and product dispensing behavior (front view)

direction when it is dispensed, potentially causing it to be jammed in the upright position. As a preventive measure, it has a function to control the posture of products by installing two layers of posture control guides under the racks, a primary guide to control the fall of products in the longitudinal direction, and a secondary guide to adjust the posture of products falling in the lateral direction. Figure 7 shows the posture control in dispensing products. In this way, we achieve a highly reliable dispensing mechanism that prevents product jamming by controlling the posture of products when they land on the conveyance chute and using a single spiral system with high storage efficiency for large products.

(2) Conveyance chute

Figure 8 shows the conveyance chute. Products that fall from the rack mechanism are received by the conveyance chute. The conveyance chute has a function for drawing the products dispensed from the racks on the left, right, front and rear sides to the center and conveying them along the slope to the outlet . The structure is integrally molded with a plastic designed for low temperatures and constructed with a low-

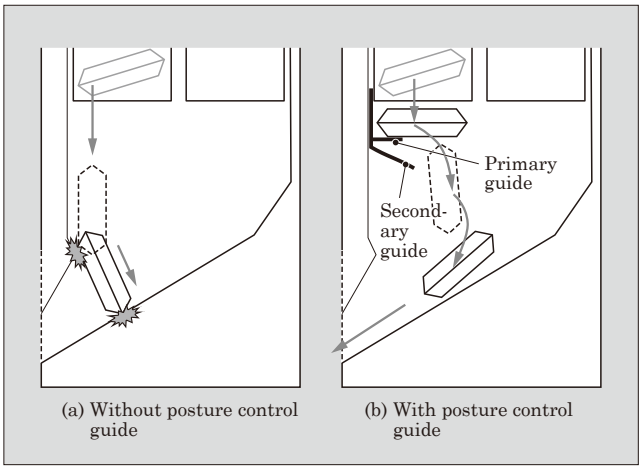


Fig.7 Posture control in dispensing products

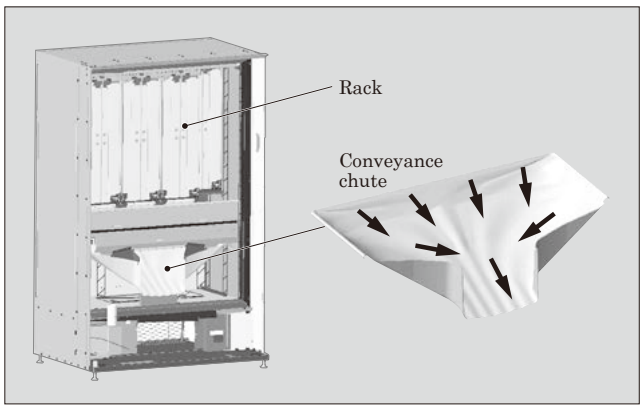


Fig.8 Conveyance chute

friction, seamless, three-dimensional curved surface structure to prevent product jamming due to snagging. However, products are becoming larger, the passage of the conveyance chute needs enlarged, which leads the center area with loose curvature become wider, raising concerns that the products would not slide down and instead get stuck. Using textured surface for the conveyance chute can reduce the contact area with the product and decrease the frictional force, allowing products to slide even on gentle slopes. We experimentally determined the relationship between the weight of the products and the contact area where the products can slide without stagnation, and reflected this in the design of the textured surface.

It is also necessary to consider the direction in which the textured surface shapes should be arranged. If textured surface shapes are arranged so that steps are formed in the conveyance direction of products, it may result in products becoming snagged. Therefore, we investigated the trajectory of products flowing against the base surface of the conveyance chute, arranged the textured surface shapes along the trajectory so as not to interfere with the movement of products sliding down, and determined the pitch of the textured surface shapes so that the contact area ratios would consist of gently curved surfaces. Figure 9 shows the arrangement of the textured surface shapes we designed for the conveyance chute. This arrangement allows a conveyance chute shape that even lightweight bagged items can slide. The contact area of the conveyance chute has been reduced to one-tenth of that of conventional products, providing stable product conveyance even under adverse conditions, such as when condensation hinders slippage.

Figure 10 shows the falling behavior of products after rack dispensing.

### 3.4 Operation support services for vending machines

This newly developed frozen food vending machine comes with a communication unit that notifies operators of the vending machine's status as a feature that supports its operation.[2] By using this feature, operators can check product sales remotely without having

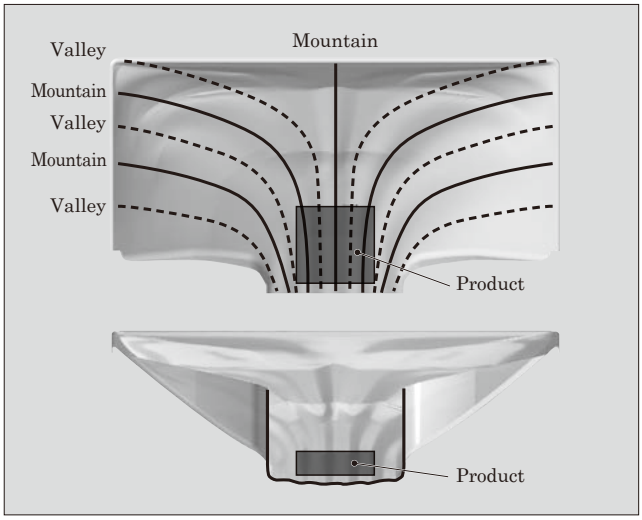


Fig.9 Arrangement of the textured surface shapes designed for the conveyance chute

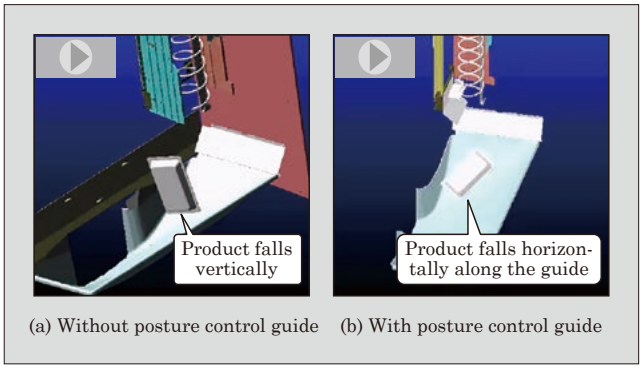


Fig.10 Falling behavior of products after rack dispensing

to visit the installation site. This also means that the vending machine can be replenished with product on a single visit.

In addition, it has a function that immediately notifies operators via email when problems occur, such as sales trouble and running out of changes, due to unskilled workers improperly replenish products or setting configurations. This facilitates prompt countermeasures and minimizes the loss of sales opportunities.

## 4. Postscript

In this paper, we introduced the "Frozen Station" frozen food vending machine. This frozen food vending machine provides the market with the ability to sell new types of products previously unavailable at stores without face-to-face interaction. Moving forward, we plan to develop technologies that accommodate various container shapes so that we can further contribute to the expansion of the frozen food vending machine market.

### References

(1) Japan Frozen Food Association. Production Volume of

Frozen Food in Japan. Https://www.reishokukyo.or.jp/statistic/statics-eng/ (accessed 2022-09-02).
(2) Katayama, S. et al. Vending Machine Operation Service Using IoT and AI to Increase Operational Efficiency. FUJI ELECTRIC REVIEW. 2021, vol.67, no.3, p.149-154.

Fuji Electric

*Innovating Energy Technology*