

# Product Dispensing Mechanism for Vending Machines for Global Market

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## ABSTRACT

The expansion and popularization of beverage vending machines in markets outside Japan has required stable power supply voltage that is not affected by different power supply voltages and unstable power conditions in some areas. To comply with the law and regulations without being affected by power conditions, Fuji Electric has adopted a low DC voltage power supply for the product-dispensing mechanism. It can supply sufficient drive energy at a low voltage by utilizing the configuration that combines a DC gear motor with a cam-linkage mechanism for the drive source used in the product-dispensing mechanism. Furthermore, we have greatly reduced the number of purchase issues that arise during the vending cycle by developing a sold-out detection structure compatible with various product shapes, as well as a malfunction detection function with detection switches.

## 1. Introduction

Although beverage vending machines have spread widely throughout Japan with approximately 2.56 million machines installed, these machines are on the cusp of widespread proliferation overseas. Expansion to the overseas market will contribute significantly to the vending machine sector in the future.

Due to the unstable power conditions and power supply voltage differences in each region, in expanding overseas it is necessary to use high-capacity transformers and other such devices to stabilize power supply voltage by raising and lowering voltages. It is also necessary to adhere to standards defined by the International Electrotechnical Commission (IEC). A policy to revise paragraph 2 of the “Electrical Appliances and Material Safety Act” ordinance in 2016 has been suggested in order to comply with IEC standards in Japan. To comply with laws and regulations without being affected by power conditions, Fuji Electric has started developing low voltage DC load devices. This paper describes our global efforts to develop a low voltage DC product-dispensing mechanism (vending mechanisms) ahead of other companies.

## 2. Development Background

Vending machines store products at ideal temperatures for drinking, and dispense and sell products selected by purchasers. Vending machines are composed of a variety of parts, such as the housing, freely opening/closing door, the vending unit that stores and dispenses products and the cooling/heating unit that heats and cools products (see Fig. 1). The vending unit

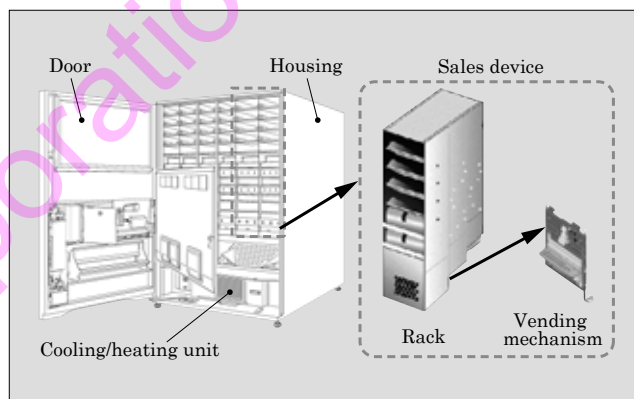


Fig.1 Vending machine product structure

is composed of a rack in which products are replenished and stacked on their side in each lane (column), and a mechanism installed on the lowest part of the rack that receives vending signals and electrically drives the vending mechanism to dispense products (see Fig. 2).

Figure 3 shows how the vending mechanism works.

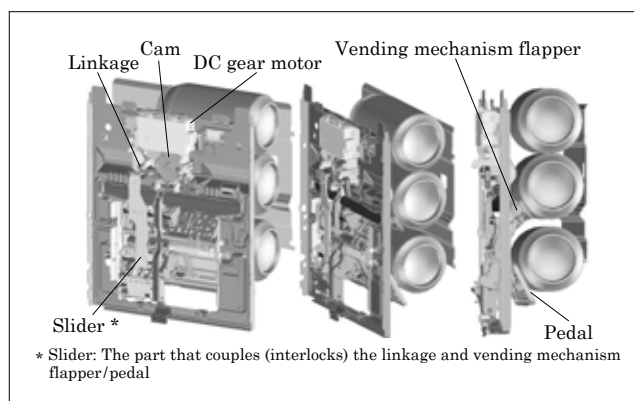


Fig.2 Vending mechanism

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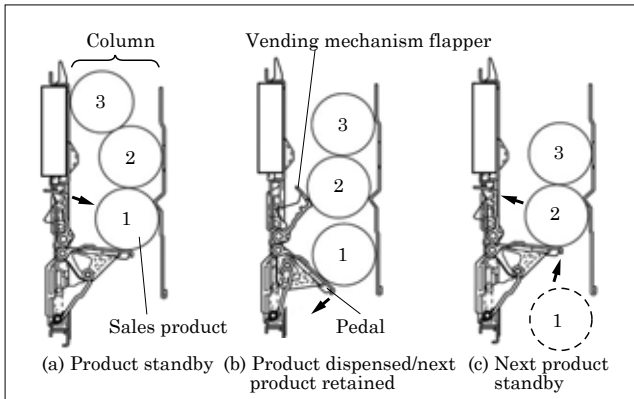


Fig.3 Vending mechanism operation

A number of products are stacked up vertically. Among them, only the product at the bottom is reliably sold, with an average load of approximately 5 kg exerted. For this reason, the vending mechanism is required to have a drive performance capable of reliably and quickly operating components such as the vending mechanism, flapper and pedal. AC solenoids that have been used as drive sources conventionally have a comparatively long operation stroke, making it easy to ensure the starting torque, holding torque and required operation speed. When an AC solenoid is used, however, high-voltage wiring is installed to support commercial power supplies such as 100 V AC in the mechanism, and this requires an insulation structure that complies with IEC standards. If the drive source of a vending mechanism that supports low voltage direct current can be achieved, an insulation structure that supports high voltage will no longer be required. Furthermore, there would be no need to prepare drive sources for commercial power supplies with differing voltages in each country and region.

### 3. Development Goals and Challenges

#### 3.1 Ensuring of drive energy while changing to low voltage DC

A high direct current voltage of approximately 80 V DC is required for a DC solenoid to simply ensure the same performance as a 100 V AC solenoid. However, a new power supply will not need to be prepared if sufficient drive energy can be ensured by using a low voltage 24 V DC power supply equipped to drive the control system of a vending machine.

#### 3.2 Sold-out detection that is not affected by product shape

Conventionally, actual machine testing was carried out to confirm whether products with various shapes could be sold, according to the guidelines established by each customer in Japan. However, as we expand overseas, it would be physically impossible to carry out actual machine testing on all products. Additionally, conventional vending mechanisms de-

tect sold-out products by shape; thus, kinds of vending products have to be confined. Ensuring sold-out detection performance even for uncertain product shapes and expanding the range of products that can be sold is one challenge in expanding overseas.

### 3.3 Jammed product detection

We have implemented a variety of mechanical measures to prevent products from getting jammed to ensure that products can continue to be dispensed from the vending unit. However, actual vending machines handle products of varying shapes, and there are nevertheless cases where products get jammed and cause problems. In addition to our efforts to improve the mechanism for preventing product jams, we have added a new way of preventing problems during purchase. We have implemented a structure where the product selection button of the vending machine will show that a product is sold out if a jam is detected in order not to inconvenience purchasers.

## 4. Features and Technology

### 4.1 DC gear motor system

We have developed a new structure that combines a cam-linkage mechanism with a DC gear motor. It serves as a low voltage DC drive source that operates at low voltage and can allow for quick round trip operation. Figure 4 shows how the driver source works in the new structure.

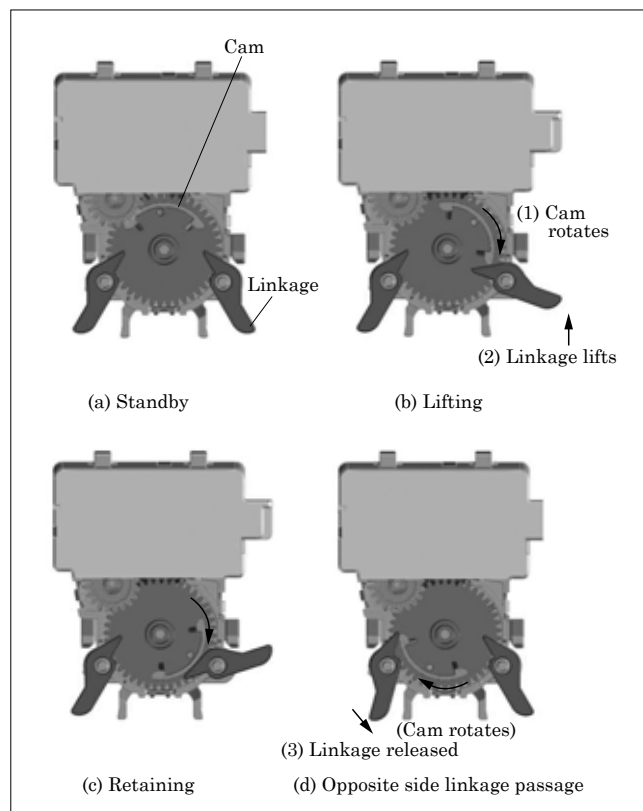


Fig.4 Drive source operation

In contrast with a conventional AC solenoid output of approximately 700 W, the DC motor has one-fifteenth the output of approximately 48 W due to constraints on space within the structure. First, we use a gear motor, which utilizes a gear to slow down a small, high-speed rotating motor, in order to ensure the required lifting power. The gear motor ensures a necessary reduction gear ratio in the limited space by using a worm gear while ensuring the required lifting power through obtaining an output torque approximately 25 times greater than the motor output. Next, we use a cam-linkage mechanism to ensure operation speed. We finely set the linkage contact surface angle to ensure a certain stroke amount, and ensure the required operation speed by obtaining the stroke required at the fine cam rotation angle.

In this mechanism, the vending mechanism flapper (see Fig. 3) operates to ensure that only the product at the bottom is sold and also other products stacked up are not accidentally sold. In order to perform this reliably, the mechanism is structured to increase the lifting speed of the linkage during the lifting operation shown in Fig. 4 (b). We also designed the structure so that the linkage is retained in the outer periphery of the cam, in order to ensure stable retention power without relying on drive power when held (see Fig. 4 (c)). With this structure, the retention status is maintained even if the power supply is shut down when held, allowing vending to continue once power is restored.

Although these structures ensure speed and retention power, the vending mechanism also needed to support a wide variety of vending product shapes, materials and sizes. With conventional AC solenoids, even if the lifting operation of the vending mechanism stopped without reaching sufficient speed for products with large diameters or square shapes, the product would be retained without causing any errors such as locking at the position it stopped. However, with a DC gear motor system, an additional mechanism was required to prevent the motor from locking.

We therefore used a plastic linkage to design a mechanism that uses part deformation caused by elasticity. Depending on the shape of the product, the mechanism may appear to come close to stopping during lifting operation. However, the linkage rotation shaft separates from the cam due to elasticity, allowing the cam to rotate. This allows the lifting operation to function properly where it would otherwise stop.

#### 4.2 2 in 1 drive system

It is desirable for operators to use vending machines capable of carrying a wider selection of products that can be sold, as well as higher numbers of individual products. For this reason, the vending mechanism was conventionally installed so that it was interlinked. The drive sources were embedded in a limited and narrow space, with each drive source driving one column.

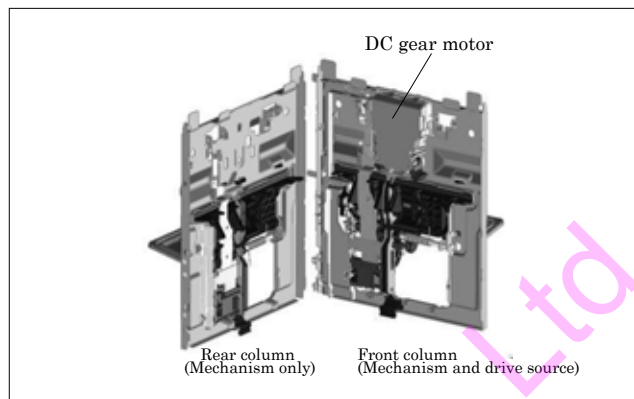


Fig.5 1 motor, 2 column drive system

If the DC gear motor was placed in the same location, it would not be able to secure the space required to gain a sufficient gear reduction ratio and cam radius. We leverage the interlinked structure to drive 2 columns with a single motor, ensuring the space that was needed (see Fig. 5).

The front and rear columns use the same gear motor and the sold-out detection drive source, as described later, making it possible to design a vending mechanism that collects all the electric driving parts on a single side, achieving improved maintainability.

#### 4.3 Sold-out detection

Figure 6 shows the sold-out detection structure. In this structure, a detection switch detects whether vending products are applying a load to the pedal. The rear column sold-out detection switches are all brought to the front column in order to improve maintainability. Furthermore, since the detection switch detects a pedal movement it can detect the dispensing state in

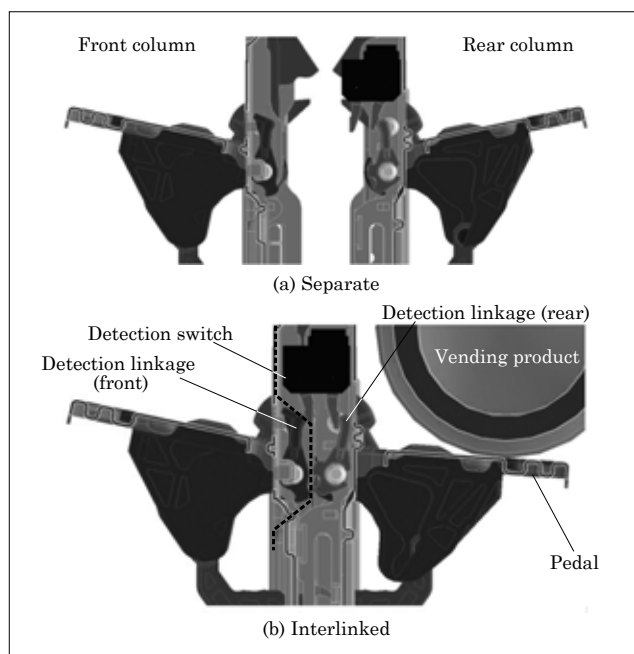


Fig.6 Sold-out detection structure

addition to whether a product is sold out. Detecting errors such as jammed products allows for more detailed support based on actual circumstances.

Conventional sold-out detection mechanisms set vending products as sold out when the last one of a product still left in the machine. This new mechanism can detect the last product remaining. This means that vending products can be sold to the last item. This increases the number of products that can be sold by an average of 7%, reducing lost sales opportunities. In addition, conventional detection mechanisms used shape detection method, and they sometimes were unable to detect products with large dented shapes. The new mechanism adopts weight detection method. Since there are no restrictions on shape, operators have much more freedom in choosing the shape of products they sell. Finally, the new mechanism directly detects vending products. This allows it to accurately determine that products are in the standby position and to prevent erroneous product detection.

#### 4.4 Jammed product detection and payment refunds

Figure 7 shows a comparison of processing when a failure occurs. The DC gear motor system and the new sold-out detection mechanism detect when mechanical vending operations are complete, making it possible to detect column failures. Product jams can be identified when motor rotation stops and the origin switch of the gear motor does not detect that it has returned to its original position.

Conventional vending mechanisms were not able to detect product jamming. Consequently, there were troubles in some cases when a purchaser occasionally intended to purchase a product even though the product could not be dispensed or there was a column failure. We have developed status detection for this mechanism, which allows it to refund payment or have the purchaser select a different product if a product becomes jammed. Additionally, separating a defective

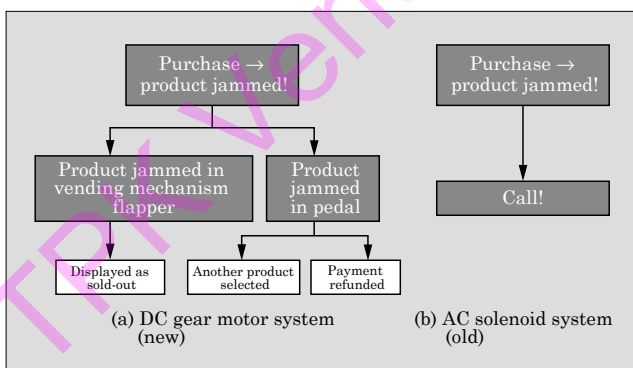


Fig.7 Comparison of failure handling processes

Table 1 Vending mechanism performance

Item	New mechanism	Conventional mechanisms	Comparison
Drive voltage	24 V DC	100 V AC	Low voltage drive
Error detection	Yes	No	Able to detect errors
Failure response	Refund/ selection of different product	Unable to detect	Prevents selection of unavailable products
Defective column separation	Able to separate → Vending stopped	Unable to separate	Prevents problems during purchase
Defective column confirmation	Display by remote control	Confirmation by actual vending	Serviceability improved
Operating noise (dB)	70	73	-3 dB
Sold-out detection	Zero	One product remaining	-7% Reduced sales opportunity losses
Product detection range (mm)	169	35	480% Improved freedom in choosing package shape
Power consumption (W·s per item)	17	175	-90%
Power consumption (W)	48	700	-93%

column allows purchasers to prevent from selecting products that cannot be dispensed, drastically reducing problems during purchase.

## 5. Results

Table 1 lists the performance gained as a result of developing this mechanism. As an added benefit, reducing power consumption also made it possible to reduce the volume and capacity of batteries used with disaster response models by 40% compared with conventional products.

## 6. Postscript

This paper described a product dispensing mechanism for vending machines in the global market. Developing this mechanism has allowed us to build technology to achieve low voltage DC drive sources. We will promote technology expansion based on this technology, in order to provide global support for drive sources in vending machines. We will continue our research and development efforts with a focus on providing added value to our customers.



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