Heating and Cooling Technology and Global Solutions for Food Distribution: Current Status and Future Outlook

SUGIMOTO, Koji*

1. Introduction

Food distribution needs are changing in Japan due to depopulation, the decreasing birthrate and aging population, increasing numbers of single households and women's participation in society. High quality products and services are needed that can meet these diversified individual needs.

Furthermore, there are increasing expectations for the development of new food distribution solutions such as vending machines overseas, following lifestyles changes especially in Asia regions.

Fuji Electric's Food Distribution Division is working to research and develop related technologies with 4 keywords in mind in order to meet these needs: "high quality," "diversification," "environment" and "global support." This paper describes these new technologies.

2. Support for High Quality and Diversification

2.1 Ultra-compact cup-type vending machine

Consumers require high quality at any locations that are close to them, such as workplaces or at home.

In order to respond to demand for high quality, freshly-made coffee at offices, Fuji Electric has developed a new cup-type vending machine that is easy to install in offices, compact and higher maintainability (see Fig. 1). The new slim machine is designed in pursuit of rich and delicious coffee. It uses a regular coffee extraction system that is a core technology in traditional cup-type vending machines and a compact cup mixing system (refer to "Office-Use Ultra-Compact Cup-Type Vending Machine 'FJX10'" on page 168).

Fig.1 Ultra-compact cup-type vending machine "FJX10"

2.2 New fixtures in convenience stores

In the convenience store industry, in addition to the traditional convenience, new high quality products are being created constantly in respond to the needs of consumers. This requires equipment development that is flexible and suits a variety of needs, such as the development of fixtures that satisfy the requirements listed below, and the development of new showcases that can hold more products.

(a) Equipment that suits new product shapes and characteristics must be provided
(b) Fixture operation must be simplified, and it must be possible for anyone to provide high quality services easily
(c) Equipment must be safe and secure from a food hygiene perspective

Fuji Electric has responded with rapid develop-

(a) Coffee machine (b) Donut fixture

Fig.2 Counter fixture

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

ment in order to launch equipment in a timely manner in line with new customer product releases (see Fig. 2).

In addition to sharing issues with the Production Division and engaging in concurrent development, this requires element technology development that captures market needs on a regular basis and that can quickly respond to demand, as typified by technologies to extract rich and aromatic coffee over a short period of time.

2.3 Support for high capacity and space saving

Fixtures used in convenience stores are required to contain many new products in a timely manner, with a limited amount of space. One example is the inverter refrigerator mounted drink showcase (see Fig. 3). This fixture offers more product display shelves, thus increasing display area while significantly reducing the amount of power consumption.

In reducing power consumption, we have developed proprietary airflow control technology for cooling within the housing and improved temperature distribution within the housing, making it possible to efficiently control temperatures with little energy.

We also analyzed the amount of power consumption and made several changes such as revising the heater that takes care of dew condensation, to eliminate energy loss as much as possible and achieve a 50% reduction in power consumption over previous models (refer to "Drink Showcase Equipped with Inverter Freezer" on page 178).

2.4 Support for multiple temperature range logistics

It is well known that transporting food at a constant temperature can retain the quality of said food. Foods are growing more diverse and the demand for higher quality products (good fresh products) is increasing. There is an increasing need for multiple temperature range logistics[*1] in which many foods are transported at their ideal temperatures. To meet this need, we have developed the "D-BOX" cold roll box pallets for delivery. Transporting food with systems that use this container allows small units of food to be transported at a constant time and temperature from production areas to stores, without using refrigerated trucks (see Fig. 4). Furthermore, this technology allows for easier direct shipments of high quality foods from production areas to stores (refer to "Cold Storage Container 'Chilled Type D-BOX'" on page 172).

Fig.3 Inverter refrigerator mounted drink showcase

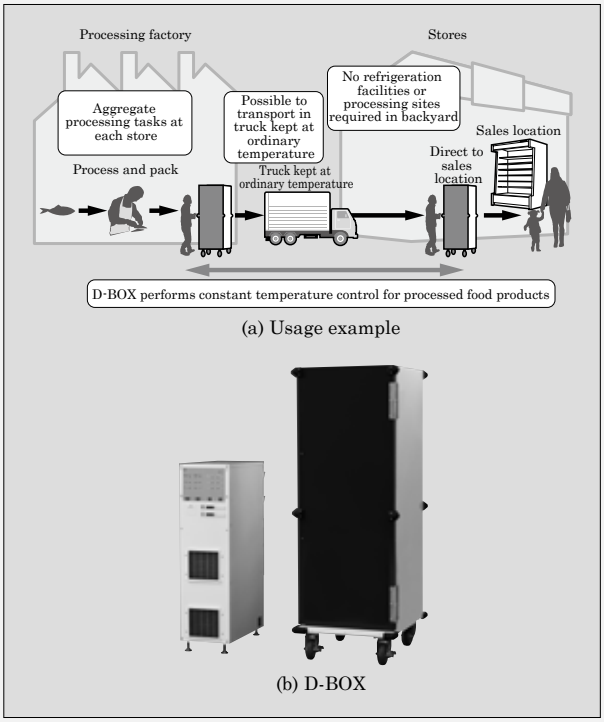

Fig.4 "D-BOX" usage example

3. Environmental Response and Energy Saving Technology

We have actively worked to reduce energy consumed by vending machines from an early stage, with the goal of preserving the global environment. Canned beverage vending machine power consumption in FY2015 fell to 17% compared with products for FY2001 (see Fig. 5). Roughly 80% of the energy consumed by vending machines is devoted to cooling and heating products (see Fig. 6).

Fuji Electric has been able to reduce power consumption through developing heat pumps, heat insulating, peak shift technology that reduces power

***1: Multiple temperature range logistics**
An optimal temperature range is required depending on each product for product distribution. This is referred to as multiple temperature range logistics, and includes all different temperature ranges, such as "frozen," "chilled" and "dry."

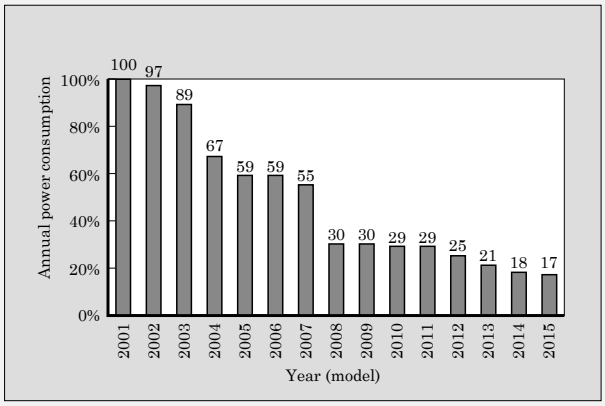

Fig.5 Power consumption trends in can and bottle beverage vending machines

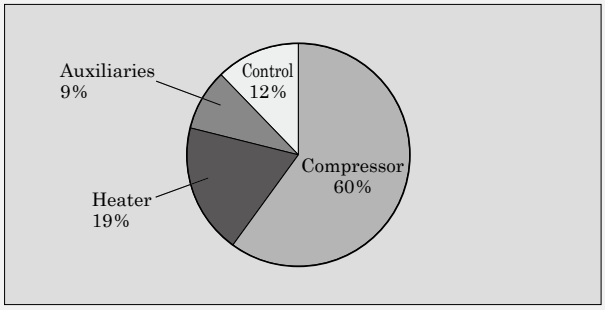

Fig.6 Electric energy distribution for canned beverage vending machine

consumption during the day, and other technologies.

3.1 Heat pump technology

Conventionally, exhaust heat generated through cooling products was thrown away outside the housing of the vending machine. Focusing on this exhaust heat, Fuji Electric was the first in the industry to release vending machines that use heat pump[*2] technology. Instead of throwing exhaust heat away, this technology uses it to heat beverages. This heat pump system cools some products while warming others, and is unique to beverage vending machines (see Fig. 7). At least 90% of the canned beverage vending machines being shipped today make use of this technology.

In order to further reduce power consumption, we brought the following 2 technologies to market in FY2014:

(1) Ejector refrigerating cycle for CO_2 based heat pump type vending machines

We were the first to install ejectors[*3], used in car air conditioners and water heaters, in vending machines that use natural CO_2 refrigerant[*4] and brought vending machines with significantly improved efficiency and reduced (25%) power consumption to market.

Conventionally, refrigeration cycles that use CO_2 refrigerant work at a higher pressure than those that use hydrofluorocarbon refrigerant[*5]. This requires more power to drive the compressor, which reduces efficiency.

Meanwhile, the ejector refrigerating cycle takes advantage of the properties of CO_2 refrigerant. By adopting a pump action mechanism to suction evaporator refrigerant that utilizes expansion-loss energy, we have achieved a reduction in energy required for compression. Furthermore, as shown in Fig. 8, a gas-liquid separator was added after the expansion stroke to separate gas suctioned by the compressor

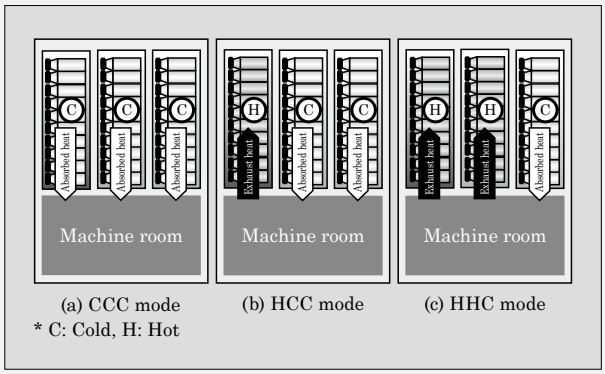

Fig.7 Heat pump heating structure

***2: Heat pump**

Heat pumps pump "heat" from low temperature parts to high temperature parts. This means that low temperature parts are even lower, while high temperature parts are even higher. This principle is also used in refrigerators and air conditioners. Refrigerant transfers heat between indoor and outdoor equipment, cooling and heating air. Heat pumps can transfer more heat than the workload of the compressor, and are drawing attention as one way to efficiently save energy. Fuji Electric vending machine heat pumps use both exhaust heat from cooling chambers and atmospheric heat in heating chambers. As switching the two heat sources as needed, the heat pumps are called "hybrid heat pumps."

***3: Ejector**

One kind of fluid pumps in which high-speed jets accelerated by nozzles draws in surrounding fluid, increasing pressure via a diffuser. They are also used for such applications as condensers in steam turbines and pumps in vacuum chucks. There are no moving parts, making them easy to maintain and usable even in clean environments. For details, refer to Supplemental explanation 1: "Ejector" on page 207.

***4: CO_2 refrigerant**

Refrigerant is a substance used in cooling to emit or absorb latent heat by changing phase from liquid to gas or gas to liquid. In contrast with conventional fluorocarbon refrigerant, CO_2 refrigerant is a natural refrigerant with an extremely small greenhouse effect that does not damage the ozone layer. It has a global warming potential of 1 (standard refrigerant when calculating potential) and an ozone depletion potential of 0.

***5: Hydrofluorocarbon refrigerant**

Hydrofluorocarbon refrigerant is an alternative chlorofluorocarbon. It is used as an alternative to specified chlorofluorocarbons (CFC). Alternative chlorofluorocarbons are refrigerants developed to curb damage to the ozone layer.

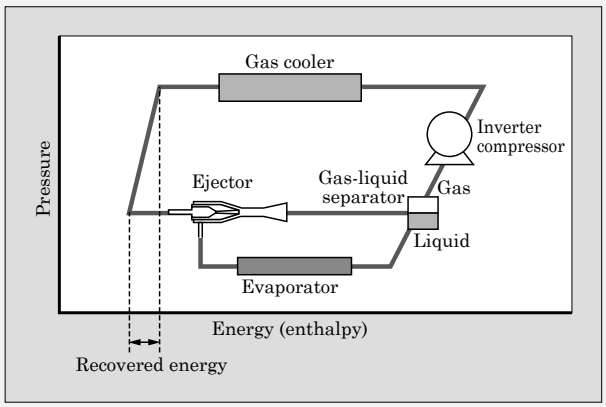

Fig.8 Ejector refrigerating cycle

and liquid refrigerant that flows to the evaporator, in order to improve refrigerator efficiency (refer to "Heat Pump Vending Machine Equipped with CO_2 Ejector Refrigerating Cycle" on page 158).

(2) ZERO heating power vending machine "Hybrid ZERO"

Fuji Electric has applied heat pump technology to develop a proprietary hybrid heat pump system that uses both exhaust heat generated when cooling products contained and outside air as heat sources. We have helped to significantly reduce the amount of power consumption by deploying this system throughout the market.

We have developed the ZERO heating power vending machine "Hybrid ZERO," which further advances heat pump technology and makes use a method that does not use the heater that was partially used depending on the season (mode), achieving a yearly power consumption that is 15% less than previous hybrid heat pump vending machines. The Hybrid ZERO heats all heating chambers using a heat pump, resulting in a significantly greater heating load fluctuation compared with previous models. Heating capability is improved by diverting heat generated from the compressor to the heat pump. To improve efficiency when less heating capability is required, we have adopted a highly efficient inverter compressor that can work at a slower speed than previous models, resulting in improved energy saving. (Refer to "ZERO Heating Power Vending Machine 'Hybrid ZERO'" on page 163.)

3.2 Heat insulating technologies

One important technological issue with vending machines is heat insulating technology to restrain heat transfer between the heating chamber and the cooling chamber. When products are cooled in one chamber while warmed in a neighboring chamber, insufficient heat insulation between the chambers will cause increased heat transfer. We have been developing technologies to restrain heat transfer through door components by thoroughly measuring vending machines to gain a complete understanding of the path heat travels when passing through parts connecting the door and housing.

In addition to these heat insulating technologies, we have developed functionality to significantly reduce power consumption throughout the day by storing heat evenly in products contained.

This functionality has been developed in response to recent circumstances of power supply. It can be used to store cool air at night, which is then utilized to make cool beverages available throughout the day, even when daytime cooling operation is stopped for a long time (peak shift technology).

3.3 Response to global warming (use of low GWP refrigerants)

With the enactment of the "Act on Rational Use and Proper Management of Fluorocarbons" (Fluorocarbons Emission Control Law) in April 2015, specific requirements to prevent global warming are now placed on the freezing-refrigerating equipment business operators.

This was originally a regulation on recovery and destruction during disposal, but now covers the use of refrigerants with a low global warming potential (GWP[*6]) and the management of fluorocarbons being used. This clearly defines the responsibilities placed on not only manufacturers, but also on freezing-refrigerating equipment business operators.

The main responsibilities are listed below. Regulations on business operators have been determined in some detail.

(1) Responsibilities concerning equipment installation
(2) Responsibilities concerning equipment utilization
  (a) Implementation of equipment inspections
  (b) Measures on leak prevention system and prohibition on filling unrepaired devices with refrigerant
  (c) Retention of inspection log
  (d) Calculation and reporting of estimated fluorocarbon leakage
(3) Responsibilities concerning equipment disposal

Fuji Electric has actively worked to use refrigerant with a low ozone depletion potential (ODP[*7]) and GWP, and to reduce the energy we use from an

***6: Global warming potential (GWP)**

GWP stands for global warming potential.

It represents the impact of greenhouse gases that cause the greenhouse effect due to some of the infrared rays radiating from the surface of the earth being absorbed, with CO_2 as the baseline (1.0). The smaller the number, the less of a greenhouse effect there is.

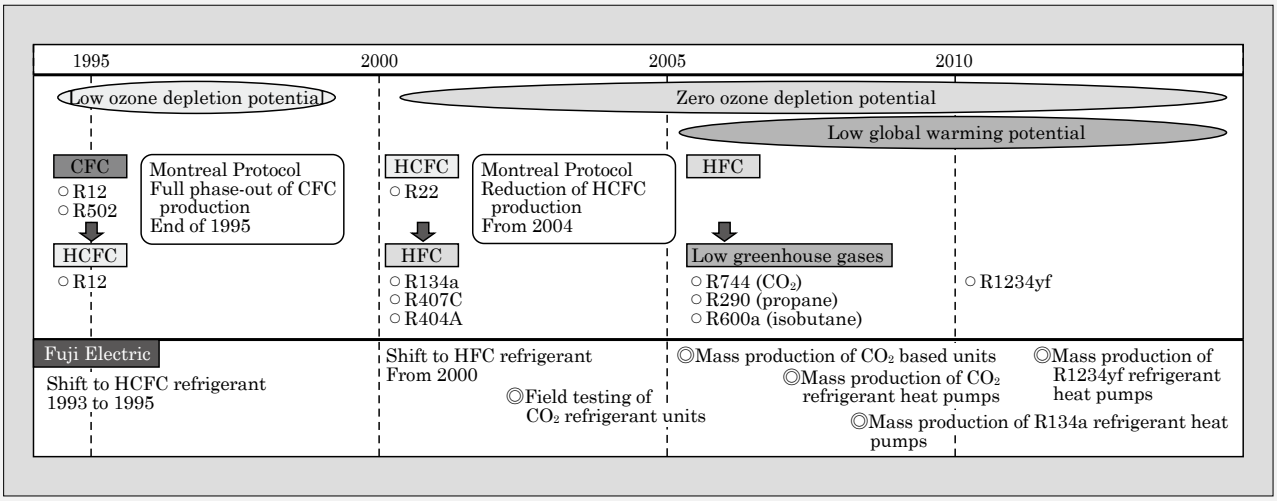

Fig.9 Refrigerant transitions

early stage (1993), with the goal of preserving the global environment (see Fig. 9).

We will successively apply the technologies for energy saving and use of low GWP refrigerants that we have accumulated through developing vending machines to stores and distribution-related products.

3.4 Next-generation showcase with built-in refrigeration system

As shown in Fig. 10, showcases installed in convenience stores and other locations currently use a refrigerator placed outside the store for central refrigerant circulation (showcases with separate refrigeration system).

Fuji Electric has used low GWP refrigerant applied technology to develop a next-generation showcase with a built-in refrigerator (see Fig. 11).

Currently, separate models use R404 A refrigerant, which has a GWP of 3,920. The refrigerant used in our newly developed next-generation showcase has a GWP of 1 or less (the same value as CO_2 refrigerant or less).

We revised the conventional air curtain system to rectify air flow within the housing, resulting in a subdivided airflow system that curbs outside air from being pulled in. This achieves a 30% reduction in required refrigerating capacity over conventional systems.

Compared with separate models whose refrig-

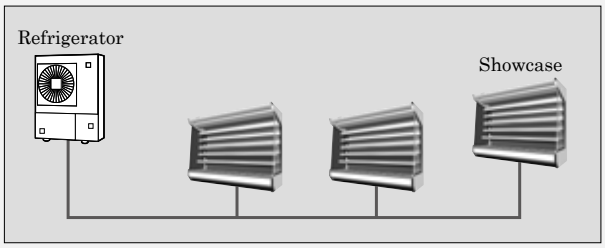

Fig.10 Showcase with separate refrigeration system

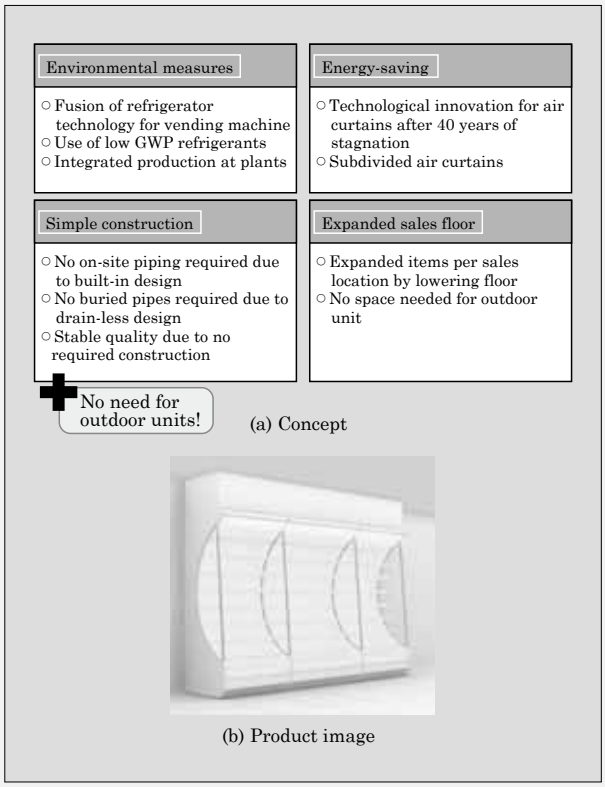

Fig.11 Next-generation showcase with built-in refrigeration system

***7: Ozone depletion potential (ODP)**

ODP stands for ozone depletion potential.

ODP is a coefficient representing the relative value of the destructive effect that unit weight substances released into the atmosphere have on the ozone layer, with CFC-11 (trichlorofluoromethane, CCl3F) set at a value of 1.0. Alternative fluorocarbons that do not include chlorine and the natural refrigerant CO_2 have an ozone depletion potential of 0.

erant pipe is installed in the store, a refrigeration circuit is installed for each showcase, reducing the total amount of refrigerant and making inspection easier. Furthermore, no coupler or mechanical seal work is required on site and brazing keeps circuits completely closed, significantly reducing the danger of refrigerant leaking. Even if refrigerant does leak, the amount will be slight, thus reducing the burden of managing refrigerant.

4. Element Technologies in Global Support of Vending Machines

Fuji Electric has vending machine manufacturing sites in Thailand and China. We proceed with globalization under a 3-site system, with our Mie Factory as the mother factory. In order to quickly respond to circumstances in each country, we have worked hard to shorten the development period by continuing to advance the establishment of our global platform[*8], in which we keep an eye on each requirement and take common points into consideration.

Prior to this, we promoted platform design in Japan, and worked to improve reliability and quality by making parts common and standardized between device categories. As a result of our efforts, around 50% of the components that go into different device categories are common. We will continue to develop these activities across the world, and promote the implementation of the global platform.

4.1 Product dispensing mechanism for the global market

AC power supply solenoids were used as drive sources for mechanisms to dispense cans and bottles. It was therefore necessary to support circumstances from region to region, such as unstable power supplies and differences in power supply voltages. Using DC motors allows us to share dispensing mechanisms among products and also makes it easier to support safety standards in each country (see Fig. 12).

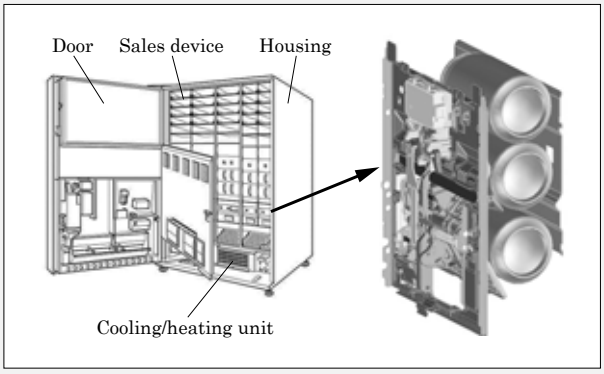

Fig.12 Product dispensing mechanism for the global market

As an added function, it is also possible to verify product dispensing status, dramatically reducing the number of malfunction support calls in the market (refer to "Product Dispensing Mechanism for Vending Machines for Global Market" on page 187).

4.2 Currency identification devices for global markets

In developing currency identification devices to support currency in China and the Association of Southeast Asian Nations (ASEAN) region, we investigated the currencies of each country, and we have improved production efficiency and shorten the development period by clarifying the fixed and variable parts.

Additionally, we have worked to reduce barriers to training new service personnel outside of Japan, such as developing new proprietary sensors and streamlining structures to improve serviceability (refer to "Currency Identification Device for Global Markets 'FGC Series' and 'FGB Series'" on page 196).

4.3 Global vending machines installed in high-temperature high-humidity environments

One important element of vending machines is cooling and heating functions. In order to reduce lost sales opportunities as much as possible, it is important to bring replenished products to their appropriate temperatures quickly.

In the Japanese criteria, required cooling performance is guaranteed assuming the ambient temperature of 32 °C. The same performance is required in environments reaching 40 °C outside of Japan especially in tropical region of Asia. For this reason, we have combined a sophisticated heat exchanger with a CO_2 refrigerant compressor in an attempt to improve cooling performance. We will be committed to achieve the performance required by the circumstances in each region by combining these cooling and heating components as a unit (refer to "Cooling Technology for Global Vending Machine Installed in High-Temperature High-Humidity Environments" on page 202).

5. Postscript

Needs for food distribution businesses are expected to grow more diverse.

***8: Global platform**
Global platform in this sense refers to common components that serves as a foundation for groups of products, in order to expand on a global level. It is separate in meaning from the computer term, which is often used to refer to the act of clarifying and categorizing which OS a computer system belongs to.

In order to remain sensitive to market changes and respond quickly, we will continue to accumulate basic technologies and engage in research and development to meet the needs of the market.