CHAPTER 47

FOOD SERVICE AND GENERAL COMMERCIAL REFRIGERATION EQUIPMENT

FOOD service requires refrigerators that meet a variety of needs. This chapter covers refrigerators available for restaurants, fast-food restaurants, cafeterias, commissaries, hospitals, schools, convenience stores, grocery stores, and other specialized applications.

Many refrigeration products used in food service applications are self-contained, and the corresponding refrigeration systems are conventional. Some systems, however, do use ice for fish, salad pans, or specialized preservation and/or display. Chapters 46 and 48 have further information on some of these products.

Generally, electrical and sanitary requirements of refrigerators are covered by criteria, standards, and inspections of Underwriters Laboratories (UL), NSF International, and the U.S. Public Health Service.

REFRIGERATED CABINETS

Reach-In Cabinets

The **reach-in refrigerator** or freezer is an upright, box-shaped cabinet with straight vertical front(s) and hinged or sliding doors (Figure 1). It is usually about 2.5 to 3 ft deep and 6 ft high and ranges in width from about 3 to 10 ft. Capacities range from about 20 to 90 ft^3. Undercounter models 3 ft high with the same dimensions are also available. These capacities and dimensions are standard from most manufacturers.

The typical reach-in cabinet (Figure 1) is available in many styles and combinations, depending on its intended application. Other shapes, sizes, and capacities are available on a custom basis from some manufacturers. Chapter 46 discusses display cabinets in great detail.

There are many varied adaptations of refrigerated spaces for storing perishable food items. Reach-ins, by definition, are medium- or low-temperature refrigerators small enough to be moved into a building. This definition also includes refrigerators and freezers built for special purposes, such as mobile cabinets or refrigerators on wheels and display refrigerators for such products as beverages, pies, cakes, and bakery goods. The latter cabinets usually have glass doors and additional lighting to illuminate the product. Candy refrigerators are also specialized in size, shape, and temperature.

Refrigerated vending machines satisfy the general definition of reach-ins; however, because they also receive coins and dispense products individually, they are classified separately. Generally, the full product load of a vending machine is not accessible to the customer as in normal reach-in cabinets. Beverage-dispensing units dispense a measured portion into a cup rather than in a bottle or can.

Reach-in refrigerators have doors on the front. Refrigerators that have doors on both front and rear are called **pass-through** or **reach-through refrigerators** (Figure 2). Doors are either full height (one per section) or half height (two per section). Doors may have windows or be solid, hinged, or sliding.

Roll-In Cabinets

Roll-in cabinets are very similar in style and appearance to reach-in cabinets, but vary slightly in construction and functionality. Roll-ins (Figure 3) are usually part of a food-handling or other

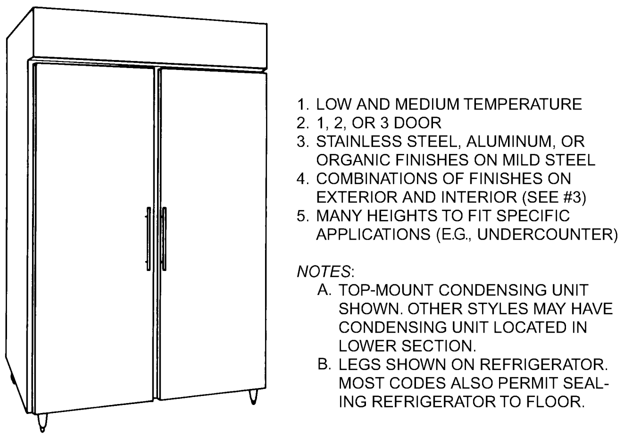

Fig. 1 Reach-In Food Storage Cabinet Features

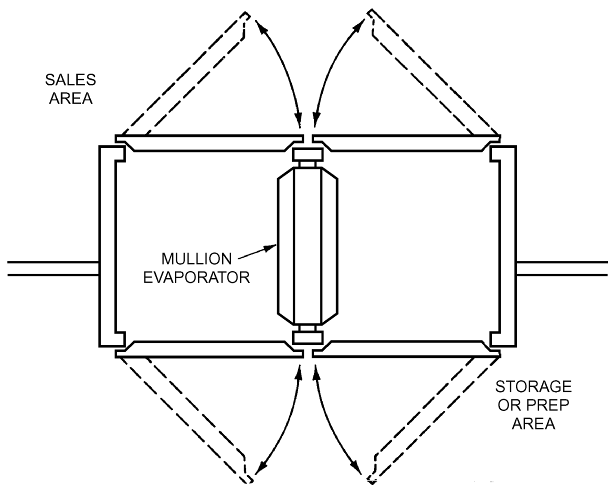

Fig. 2 Pass-Through (Reach-Through) Refrigerator

The preparation of this chapter is assigned to TC 10.7, Commercial Food and Beverage Cooling, Display and Storage.

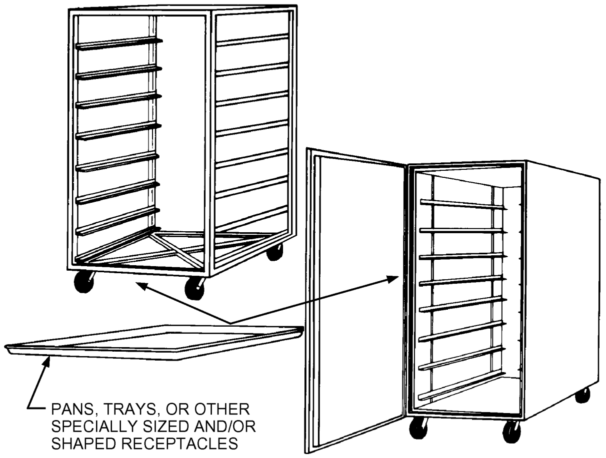

Fig. 3 Open and Enclosed Roll-In Racks

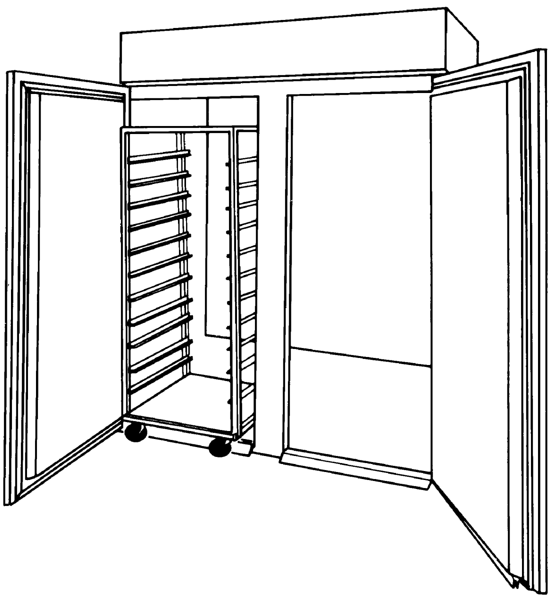

Fig. 4 Roll-In Cabinet, Usually Part of Food-Handling or Other Special-Purpose System

special-purpose system (Figure 4). Pans, trays, or other specially sized/shaped receptacles are used to serve a specific system need, such as the following:

- Food handling for schools, hospitals, cafeterias, and other institutional facilities
- Meal manufacturing
- Bakery processing
- Pharmaceutical products
- Body parts preservation (e.g., blood)

The roll-in differs from the reach-in in the following ways:

- The inside floor is at about the same level as the surrounding room floor, so wheeled racks of product can be rolled directly from the surrounding room into the cabinet interior.
- Cabinet doors are full height, with drag gaskets at the bottom.
- Cabinet interiors have no shelves or other similar accessories.

Product Temperatures

Refrigerators are available for medium- or low-temperature ranges. The medium-temperature range has a maximum of 41°F and a minimum of 33°F core product temperature, with the most desirable average temperature close to 38°F. Low-temperature refrigerators cover a range of core product temperatures between –10 and +10°F. The desirable average core product temperature is 0°F for frozen foods and –5°F for ice cream. Both temperature ranges are available in cabinets of many sizes, and some cabinets combine both ranges.

Typical Construction

Refrigerators are available in two basic types of construction. The older style is a wood frame substructure clad with a metal interior and exterior. The newer style is a welded assembly of exterior panels with insulation and liner inserts.

Exterior. Materials used on exteriors (and interiors) are stainless steel, painted steel, aluminum-coated steel, aluminum, and vinyl-clad steel with wood grain or other patterns. The requirements are for a material that (1) matches or blends with that used on nearby equipment; (2) is easy to keep clean; (3) is not discolored or etched by commonly used cleaning materials; (4) is strong enough to resist denting, scratching, and abrasion; and (5) provides the necessary frame strength. The material chosen by an individual purchaser depends a great deal on layout and budget.

Interior. Shelves, usually three or four per full-height section, are standard interior accessories. Generally, various types of shelf standards are used to provide vertical shelf adjustment.

Racks for roll-in cabinets are generally fitted with slides to handle 18 by 26 in. pans, although some newer systems call for either 12 by 20 in. or 12 by 18 in. steam table pans. Racks designed for special applications are available but usually custom designed.

Manufacturers and contractors offer various methods of floor insulation. This is important if the roll-in holds frozen food.

Specialty Applications

Reach-in and roll-in cabinets are regularly modified and adapted to fit the needs of many specialty applications. Variations from standard construction practices are needed to meet the different temperature, humidity, product volume, cleanliness, and other specifications of various refrigeration applications.

Food Service. These applications often require extra shelves or tray slides, pan slides, or other interior accessories to increase food-holding capacity or make operation more efficient. Because certain stored foods create a corrosive atmosphere in the enclosure, the evaporator coil may have special coatings or fin materials to prevent oxidation. As use of foods prepared off-premises increases, on-site storage cabinets are becoming more specialized; there is growing pressure for designs that consider new food shapes, as well as in-and-out handling and storage.

Beverage Service. If reach-ins are required, standard cabinets, are used, except when glass doors and special interior racks are needed for chilled product display. These cabinets generally have oversized refrigeration systems to allow for product pulldown cooling.

Meal Factories. These applications, which include airline or central feeding commissaries, require rugged, heavy-duty equipment, often fitted for bulk in-and-out handling.

Retail Bakeries. Special requirements of bakeries are the dough retarder refrigerator and the bakery freezer, which permit the baker to spread the work load over the entire week and to offer a greater variety of products. The recommended temperature for a dough retarder is 36 to 40°F. The relative humidity should be in excess of 80% to prevent crusting or other undesirable effects. In the freezer, the temperature should be held at 0°F. All cabinets or wheeled racks should be equipped with racks to hold 18 by 26 in. bun pans, which are standard throughout the baking industry.

Retail Stores. Stores use reach-ins for many different nonfood items. Drugstores often have refrigerators with special drawers for storing biological compounds. (See the section on Nonfood Installations.)

Retail Florists. Florists use reach-in refrigerators for displaying and storing flowers. Although a few floral refrigerator designs are considered conventional in the trade, the majority are custom built. The display refrigerator in the sales area at the front of the shop may include a picture window display front and have one or more display access doors, either swinging or sliding. A variety of open refrigerators may also be used.

For the general assortment of flowers in a refrigerator, most retail florists have found best results at temperatures from 40 to 45°F. The refrigeration coil and condensing unit should be selected to maintain high relative humidity. Some florists favor a gravity cooling coil because the circulating air velocity is low. Others, however, choose forced-air cooling coils, which develop a positive but gentle airflow through the refrigerator. The forced-air coil has an advantage when in-and-out service is especially heavy because it provides quick temperature recovery during these peak conditions.

Nonfood Installations. Various applications use a wide range of reach-ins, some standard except for accessory or temperature modifications and some completely special. Examples include (1) biological and pharmaceutical cabinets; (2) blood bank refrigerators; (3) low- and ultralow-temperature cabinets for bone, tissue, and red-cell storage; and (4) specially shaped refrigerators to hold column chromatography and other test apparatus.

Blood bank refrigerators for whole blood storage are usually standard models, ranging in size from under 20 to 45 ft^3, with the following modifications:

- Temperature is controlled at 37 to 41°F.
- Special shelves and/or racks are sometimes used.
- A temperature recorder with a 24 h or 7 day chart is furnished.
- An audible and/or visual alarm system is supplied to warn of unsafe blood temperature variation.
- An additional alarm system may be provided to warn of power failure.

Biological, laboratory, and mortuary refrigerators involve the same technology as refrigerators for food preservation. Most biological serums and vaccines require refrigeration for proper preservation and to retain highest potency. In hospitals and laboratories, refrigerator temperatures should be 34 to 38°F. The refrigerator should provide low humidity and should not freeze. Storage in mortuary refrigerators is usually short-term, normally 12 to 24 h at 34 to 38°F. Refrigeration is provided by a standard air- or water-cooled condensing unit with a forced-air cooling coil.

Items in biological and laboratory refrigerators are kept in specially designed stainless steel drawers sized for convenient storage, labeled for quick and safe identification, and perforated for proper air circulation.

Mortuary refrigerators are built in various sizes and arrangements, the most common being two- and four-cadaver self-contained models. The two-cadaver cabinet has two individual storage compartments, one above the other. The condensing unit compartment is above and indented into the upper front of the cabinet; also, ventilation grills are on the front and top of this section. The four-cadaver cabinet is equivalent to two two-cadaver cabinets set together; the storage compartments are two cabinets wide by two cabinets high, with the compressor compartment above. Six- and eight-cadaver cabinets are built along the same lines. The two-cadaver refrigerator is approximately 38 in. wide by 94 in. deep by 77 in. high and is shipped completely assembled.

Each compartment contains a mortuary rack consisting of a carriage supporting a stainless steel tray. The carriage is telescoping, equipped with roller bearings so that it slides out through the door opening, and is self-supporting even when extended. The tray is removable. Some specifications call for a thermometer to be mounted on the exterior front of the cabinet to show the inside temperature.

Refrigeration Systems

Reach-in cabinets can be supported by either remote or self-contained refrigeration systems. The following two types of systems apply to all types of refrigeration equipment.

Self-contained systems, in which the condensing unit and controls are built into the refrigerator structure, are usually air-cooled and are of two general types. The first type has the condensing unit beneath the cabinet; in some designs it takes up the entire lower part of the refrigerator, whereas in others it occupies only a corner at one lower end. The second type has the condensing unit on top.

Remote refrigeration systems are often used if cabinets are installed in a hot or otherwise unfavorable location where noise or heat of the condensing units would be objectionable. Other special circumstances may also make remote refrigeration desirable.

There are tradeoffs associated with locating a self-contained condensing unit beneath the refrigerator; although the air near the floor is generally cooler, and thus beneficial to the condensing unit, it is usually dirtier. Putting the condensing unit on top of the cabinet allows full use of cabinet space, and, although air passing over the condenser may be warmer, it is cleaner and less obstructed. Having the condensing unit and evaporator coil in the same location provides a refrigeration unit that can be removed, serviced, and replaced in the field as a whole. Servicing can then be done at an off-site repair facility.

FOOD FREEZERS

Some hospitals, schools, commissaries, and other mass-feeding operations use on-premises freezing to level work loads and operate kitchens efficiently on normal schedules. Industrial freezing equipment is usually too large for these applications, so operators use either regular frozen food storage cabinets for limited amounts of freezing or special reach-ins that are designed and refrigerated to operate as batch-type blast freezers.

Chapter 16 covers industrial freezing of food products.

BLAST CHILLERS AND BLAST FREEZERS

These types of units are designed to rapidly chill or freeze food immediately after it has been cooked. Blast chillers and freezers are used by food-service establishments, such as restaurants, hotels, and cafeterias, that cook large quantities of food items, chill or freeze them, and later reheat portions to be served. Blast chillers are designed to allow operators to comply with food preparation, handling, and storage guidelines on preventing the growth of dangerous bacteria. These guidelines mandate that food be cooked to a minimum core temperature of 160°F and held there for at least 2 minutes. The food is then immediately cooled to between 33 and 38°F within 2 to 4 hours. This not only prevents bacterial growth, but also helps preserve the appearance, flavor, texture, and nutritional value of the food. Once cooled, refrigerated food must be stored at a temperature range of 33 to 38°F for a period not to exceed 5 days. Frozen food must be maintained below 0°F and can be kept for 8 weeks or longer.

Blast chillers for refrigerated food, and blast freezers for frozen food, are available in reach-in and roll-in models in a variety of sizes and capacities. They are designed to operate both as blast chillers and as storage refrigerators or freezers. Most units automatically change over to storage mode when the blast-chill cycle is completed. Many models are equipped with sophisticated microprocessor control systems that allow the operator not only to program the chill cycle, but also to obtain readouts, printouts, and alarms that document and monitor the entire process. Built-in food probes are commonly used to take readings and allow the control system to make adjustments if necessary.

WALK-IN COOLERS/FREEZERS

Walk-in coolers/freezers are used in a wide variety of applications, but food sales and service facilities dominate all other uses.

This type of commercial refrigerator is a factory-made, prefabricated, modular version of the built-in, large-capacity cooling room.

A walk-in cooler's function is to store foods and other perishable products in larger quantities and for longer periods than reach-in refrigerators/freezers. Good refrigeration practice requires storing dissimilar unpackaged foods in separate rooms because they require different temperatures and humidity and to prevent odors from some foods from being absorbed by others. The food cooler/freezer is likely to be equipped with sturdy, adjustable shelving about 18 in. deep and arranged in tiers, three or four high, around the inside walls; another common option is rolling racks (basically shelving on wheels), which are rolled directly into and out of the cooler. Large food operations may have three rooms: one for fruits and vegetables, one for meats and poultry, and one for dairy products. A fourth room, at 0°F, may be added for frozen foods. Smaller food operations that use appropriate food packaging may require only two rooms: one for medium-temperature refrigeration and one for frozen storage.

Operating Temperatures

There are two major temperature classes of walk-ins: low (–20 to –10°F) and medium (–10 to 30°F). Coolers may be used to hold sides or quarters of beef, lamb carcasses, crates of vegetables, and other bulky items. Food operations now rarely use such items. If they do, the items are broken down, trimmed, or otherwise processed before entering refrigerated storage. The modern cooler is not a storage room for large items, but a temporary place for quantities of small, partially or totally processed products.

Typical Construction

Walk-in coolers/freezers are composed of prefabricated panels, which come in a variety of sizes that are shipped to the operator and assembled on site. The edges of the panels are usually of tongue-and-groove construction and either fitted with a gasket material or provided with suitable caulking material to ensure a tight vapor seal when assembled. In most cases, the panels, refrigeration components, and controls are ordered separately and assembled on site, although some smaller units are supplied fully assembled. Sizes are typically 80 to 750 ft^2 and 8 to 10 ft high, or about 640 to 7500 ft^3; the average size appears to be in the range of 2000 ft^3. The modular walk-in cooler/freezer offers flexibility over the built-in type. It can be easily erected and moved, and readily altered to meet changing requirements, uses, or layouts by adding standard sections. Modular walk-in coolers/freezers can be erected outside a building, providing more refrigerated storage with no building costs except for footings and an inexpensive roof supported by the cooler. Exterior and interior surfaces may be painted and can be made of galvanized steel, aluminum, aluminum-coated steel, stainless steel, or vinyl-clad steel.

The frames are filled with insulation and are covered with metal on both sides. Polyurethane and polystyrene are two common types of insulation. These foam plastic materials are both light and water-resistant, and have improved thermal insulation in both self-contained and remotely refrigerated sectional coolers.

Door Construction

A variety of optional accessories simplify opening and closing doors. Triple-pane windows (heated on freezers), digital thermometers, and light switches allow an operator to locate or inspect the contents of the cooler/freezer without entering. An interior/exterior kick plate provides protection when using ones foot to kick open or close the door. Cam-lift hinges allow the door to swing open easily, and should be coupled with an automatic door closer.

Walk-In Floors

Modular (insulated) floors can be purchased and integrated into walk-in coolers/freezers, but the raised entry level requires a step or ramp entry. Walk-in coolers (medium-temperature) called *floorless* by the supplier are furnished with floor splines to fasten to the existing floor to form a base for the wall sections. Generally, floor refrigeration losses are considered small in a floorless configuration.

Level entry is becoming more important as the use of hand and electric trucks increases. The advantage and convenience of level entry afforded by a floorless cooler can also be obtained by recessing a sectional insulated floor. Walk-in coolers (medium-temperature) are the only applications that can be floorless or mounted on slab concrete. Walk-in freezers must feature an insulated floor.

Refrigeration Systems

Walk-ins can be served by remote or self-contained refrigeration equipment (see the section on Refrigerated Cabinets for more details). There are various methods of application for self-contained refrigeration units (Figure 5). These self-contained units use complete refrigeration systems, usually air-cooled, in a single compact package. The units are installed in the sectional cooler/freezer wall or ceiling panels.

Compressors

Walk-in coolers/freezers typically use either hermetic or semihermetic compressors. **Hermetic compressors** are typically rated between 1/2 and 5 hp. The compressor and motor are sealed in a gastight shell; when repairs are needed, the shell must be cut open and then resealed by welding it closed. Typical applications for the hermetic compressor are smaller food service, ice machines, and beverage dispensers. **Semihermetic compressors** can have ratings between 1/4 and 15 hp. They need less maintenance and have longer life cycles (up to three times the life of hermetics), and provide a greater cooling capacity. Furthermore, the unit not being housed in a shell allows for easy serviceability. Semihermetic compressors are typically used in larger cooling applications. See Chapter 34 of the 2004 *ASHRAE Handbook—HVAC Systems and Equipment* for more compressor information.

Evaporators

Evaporator coils are constructed of rust-free aluminum housing containing staggered copper tubes expanded into corrugated aluminum fins. The evaporator fan motors are either 115 or 230 V. Walk-in coolers (medium-temperature) typically feature an off-cycle

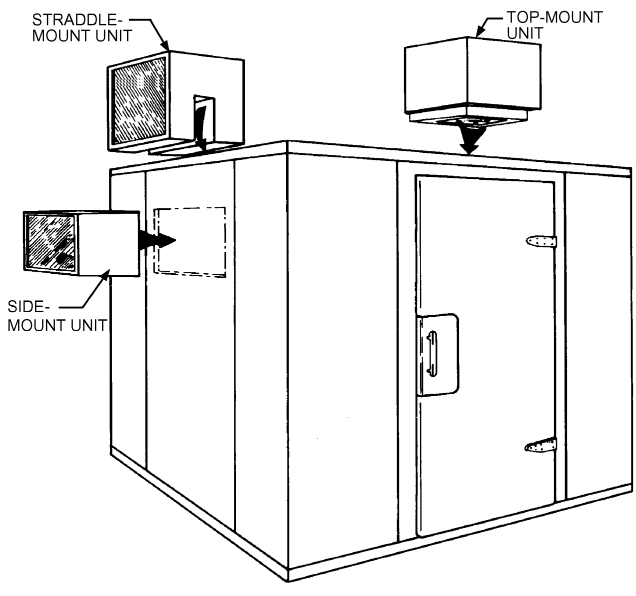

Fig. 5 Refrigeration Equipment Added to Make a Walk-In Cooler Self-Contained

defrost, whereas freezers (low-temperature) use electric defrost or hot-gas methods.

Refrigeration Sizing

When sizing the refrigeration system for a walk-in cooler or freezer, consider the following factors:

- Heat transmission (heat gained through the walls, floors, and ceiling)
- Air infiltration
- Product load (heat removed from a product to cool it, and heat of respiration from some fruits and vegetables)
- Supplemental loads (heat dissipated by people or mechanical equipment inside the cooler/freezer)
- Post-defrost pulldown load

Maintenance and Operation

- Clean the condenser coil quarterly. This will increase the refrigerator's efficiency and extend the life of the equipment by reducing compressor run time. Also, make sure air moves freely around the compressor and condenser to help the system disperse heat.
- To prevent warm, moist air infiltration into the cooler, ensure that the gaskets are in good condition, the door's hinges are lubricated, the auto-door closers are working, and, for walk-in coolers, that strip curtains have been installed.
- Keep the refrigerator's evaporator coils clean, and check them on a regular schedule. Also, check for plastic bags, which can get caught against the evaporator, on the back side of walk-in cooler units.
- Maintain proper loading of products inside the cooler to avoid blocking air circulation.
- Keep the refrigerator's evaporator drain line clean and open. Often, pooled water on the bottom a cooler results from a plugged drain line. This makes the unit work harder and longer, thus consuming more energy.
- In walk-in freezers, place heat tape in the evaporator's drain line to ensure proper drainage during defrost. In addition, make sure insulation is installed over the evaporator's drain line with heat tape, to reduce the amount of heat load inside the freezer.
- Make sure defrost time clocks are set properly and do not defrost more than necessary. Avoid defrosting during peak demand rate times, (typically between noon to 6:00 PM), when scheduled deliveries arrive, or when employees place a heavy use load on the freezer. When a freezer goes into its defrost cycle, heat is added to the evaporator (to defrost) and the compressor will not cycle on regardless of the cooler's temperature. Thus, avoiding adding heat to the freezer during the defrost times reduces a freezer's energy consumption.
- Turn off lights inside glass-door coolers at night, when customers are not present, and leave them off all of the time in noncustomer areas. This saves energy and add less heat load to the cooler.
- Ensure high integrity of vapor barriers and insulated panels. Check regularly for punctured or broken panels and breaches around pipe penetrations through the panels.

VENDING MACHINES

Refrigerated vending machines are designed to store food and beverages at a prescribed temperature and dispense product in exchange for currency. The U.S. refrigerated vending machine population is approximately 4,100,000, of which about 87% dispense canned and bottled beverages (Figure 6). The average energy usage for a typical vending machine is 3000 kWh/year and is affected by many factors (A.D. Little 1996). Generally, site owners are responsible for energy costs.

Types of Refrigerated Vending Machines

Vending machines can be divided into two main categories: closed-front and glass-front. **Closed-front units** house products inside a completely opaque insulated compartment. Some models have a display window where sample products are placed in view, but the products to be vended are contained behind an insulated door and cannot be seen by the consumer. These machines typically have a full-sized illuminated advertisement panel on the front. **Glass-front units** have a translucent panel that enables the purchaser to see the product as it is vended. In this type of machine, the product itself is illuminated and used to attract the purchaser's attention. There are various vending configurations but all machines fit into one of these categories.

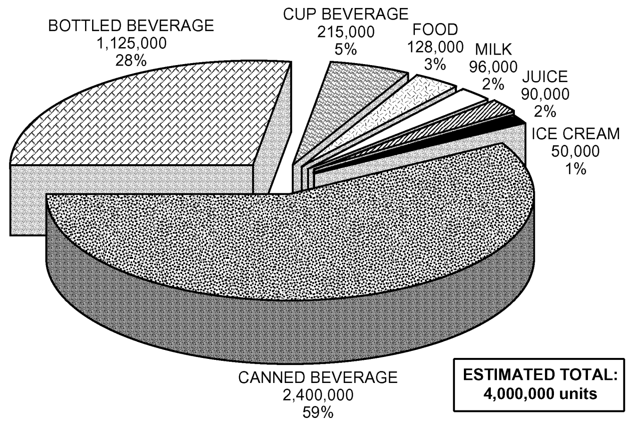

Fig. 6 Estimated 1994 Breakdown of Beverage Vending Machines by Type
(*Source*: A.D. Little 1996)

Refrigeration Systems

Vending machines use simple, self-contained refrigeration systems consisting of a compressor, evaporator coil, condenser, and capillary tube. The compressor and condenser are typically located at the bottom of the unit, between the ground and the refrigerated cabinet. Refrigerant is piped through the capillary tube to an evaporator inside the refrigerated cabinet.

The compressor consumes by far the most energy in the vending machine. Laboratory test results (Faramarzi 2005) indicate the compressor accounts for 65 to 75% of the total energy consumed (Figure 7). Oversized single-speed compressors are commonly used to provide excess cooling capacity to pull down product temperatures quickly after the machine is restocked. A condenser fan operates concurrently with compressor cycling and uses less than 10% of the total energy. The evaporator fan runs continuously to distribute air through the refrigerated cabinet and consumes about 8% of total machine energy. Lighting systems usually remain on the entire time a vending machine is plugged in. Different lighting systems are used, depending on the machine, but usually consume 5 to 20% of the total energy. Dispensing mechanisms operate intermittently, whenever a product is purchased, and therefore do not use a significant amount of energy (1 to 3%) compared to other components.

Cooling Load Components

Heat enters the refrigerated section of the cabinet by the following methods:

- Released by the evaporator fan motor
- Released by the lighting (glass-front units only)
- Conduction through the insulated envelope
- Infiltration through imperfections in construction such as cracks in the box or improperly sealed delivery doors
- Radiation through the glass front (glass-front units only)
- Product restocking (warm product placed into the machine must be cooled to acceptable temperature)

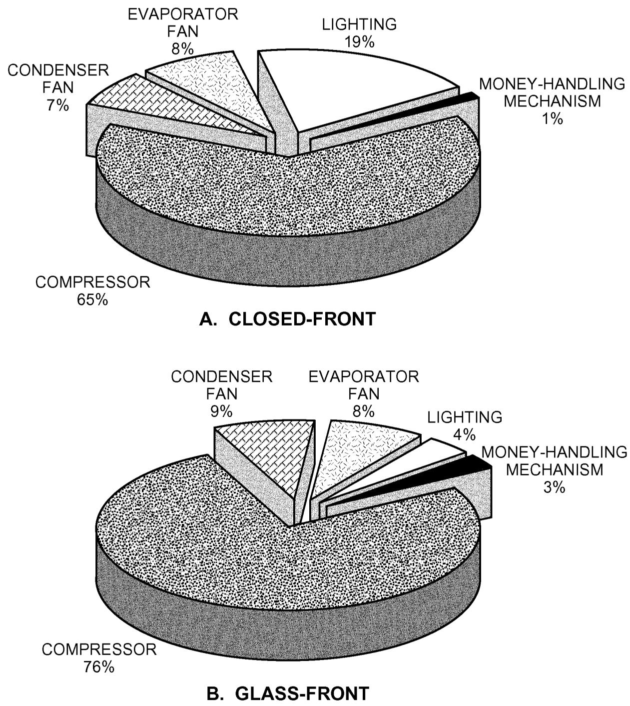

Fig. 7 Energy Use by Component For Typical Vending Machines

Data are for 24 h test with ambient conditions 95°F and 65% rh.
(*Source*: Faramarzi 2005)

Sensitivity to Surroundings

A vending machine's refrigeration system is highly vulnerable to changes in its surroundings. Cooling load can be increased by high ambient temperatures, which raise head pressure, resulting in loss of refrigeration effect and increased compression ratio. It also increases conduction, radiation, and sensible infiltration loads. High humidity increases latent infiltration load, and can cause extreme ice build-up on the evaporator coil. This may severely restrict airflow through the unit and minimize the amount of heat absorbed by the refrigerant. Exposure to sunlight greatly increases heat gain into the refrigerated space through direct solar radiation, especially in glass-front machines, raises the sol-air temperature of the cabinet exterior, and increases conduction load. Exposure to high-intensity lighting fixtures can have a similar (but smaller) effect.

Condenser coils are usually located in the bottom of the machine, with air intakes at ground level. The coils often get dirty and clogged. Dirty condenser coils lose their heat rejection effectiveness, which reduces refrigeration capacity and increases compressor power use.

Steel security cages are often placed around machines, especially when they are outdoors. These cages trap heat rejected by the condenser as it exits the rear of the machine. Trapped heat increases the inlet air temperature at the condenser, causing operations at higher condensing temperatures.

Maintenance and Operation

The site owner can improve vending machine efficiency by taking these measures:

- Keep machines in cool/shaded locations to minimize sun exposure
- Keep condenser coils clean.
- Install a controller that will shift the unit to low power based on low traffic or low sales rate.

ICE MACHINES

Ice machines are used in many commercial applications, including bars, restaurants, gas stations, minimarts, delis, hotels, motels, hospitals, and other institutional facilities. Ice machines can harvest large quantities of ice and store it in holding bins, similar to those found in hotel hallways next to vending machines or in restaurant kitchens, where it is available for later use. Restaurants and minimarts, as well as other operations, require self-service ice production, typically integrated into fountain beverage dispensers.

There are three main categories of ice machines: (1) cubers, (2) flakers, and (3) nugget (chewable ice) makers. Ice machines come in various sizes, with harvest rates between 250 and 1400 lb per 24 h. The Air-Conditioning and Refrigeration Institute (ARI) maintains a database on certified commercial ice machines and storage bins (ARI 2005), which tabulates ice harvest capacity, potable water use, and energy consumption rate for all models. In addition, condenser water use is tabulated for water-cooled models.

Typical Operation and Construction

Ice is created and then harvested, dropping into the storage bin until the bin fills up, at which point ice production stops. When the level of ice in the storage bin falls below a threshold amount, the head unit cycles back on and refills the bin.

Similar to all mechanical refrigeration, ice machines are comprised of a compressor, evaporator, expansion valve, and condenser. Cubed ice forms on the evaporator plate. When the ice is fully formed, the refrigeration system cycles in reverse, heating the evaporator plate and melting a small layer of ice to release the sheet into the storage bin. Various methods are used to release the sheet of ice from the evaporator plate. Flake and nugget machines form ice on the inside of a cylinder, which features a screw (auger) that shaves off the ice. Shaved ice is forced out the top, where it falls into a storage bin. The nugget machine adds a cone for the ice to pass through, allowing the shavings to clump together and form nuggets. Flake and nugget machines use all the water that enters the ice machine to produce ice. Cube machines use a small amount of water to purge scale and mineral deposits, to prevent damage to the evaporator plate. Head units and storage bins can be mixed and matched to meet specific production and demand characteristics of the installation.

Storage bins come in multiple sizes, and are insulated with foamed-in-place polyurethane, with doors that are hinged to stay open during ice removal. No mechanical refrigeration is used to maintain the frozen ice in the storage bin (i.e., ice machines only use energy while making ice).

Refrigeration Systems

Each category of ice machine can have a remote or self-contained air- or water-cooled condenser. See the section on Refrigerated Cabinets for a more detailed description of refrigeration systems.

Maintenance and Operations

The site owner should ensure proper ice machine performance by adhering to the manufacturer's recommended maintenance schedule and monitoring the following parameters (Moore 2000):

- Perform regular cleaning and sanitization to discourage bacterial growth.
- Check water system and evaporator for scale build-up.
- Check for talc or mineral build-up in reservoir.
- Check pump motor operation (e.g., broken impeller, slow pumping).
- Check water flow through external water filter.
- Check strainer, inlet water valve screen, or float valve for obstruction.
- Inspect float valve assembly, adjustment, and operation.
- Check air filter, condenser fan blade, and coil for dust and grime.

- Check for proper drainage or water back-up in the bin that can melt ice away.
- Inspect the water overflow of the reservoir that washes ice away.
- Check the bin control for proper location and operation.

PREPARATION TABLES

The preparation (or "prep") table is a box-shaped cabinet with an open top section and sliding drawers or hinged doors on the bottom storage compartment (Figure 8). It is usually about 2 1/2 to 3 ft deep and 3 ft high, and ranges in width from about 3 to 10 ft. The prep table is designed to hold and provide easy access to pans of food or condiments. Cabinet capacities range from about 10 to 40 ft^3. A unit may or may not be equipped with a lower refrigerated compartment. These capacities and dimensions are standard from most manufacturers.

Typical types of prep tables include refrigerated sandwich units, pizza preparation tables, and buffet tables. Prep tables, by definition, are medium-temperature refrigerators small enough to be moved into a building.

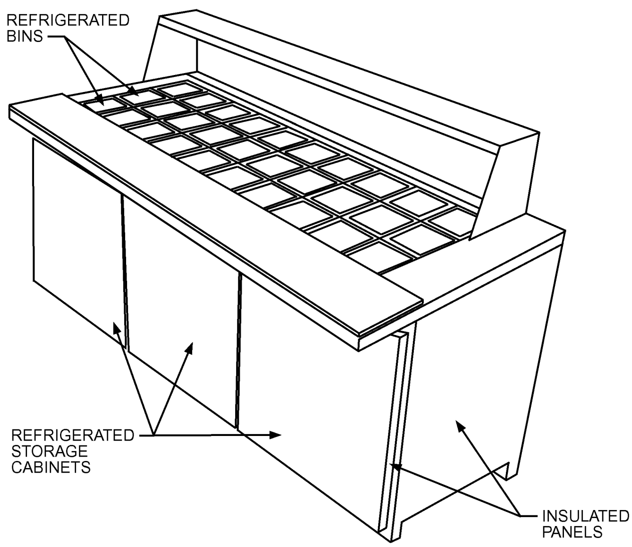

Fig. 8 Refrigerated Preparation Table

Product Temperatures

Refrigerated prep tables are available for medium-temperature ranges: a maximum of 41°F (for potentially hazardous foods) and a minimum of 33°F core product temperature, with the most desirable average temperature close to 38°F. The refrigerated rail is required to maintain food product between 33 and 41°F. Maintaining uniform bin product temperatures in prep tables is always a challenge. Cooling is provided by circulation of cold air under bins. Air does not reach each bin evenly, causing exposure of some bins to larger air volumes and, consequently, varying air temperature.

Typical Construction

Refrigerated prep tables are available in two basic types of construction. Cold wells may be designed to drop into existing countertops, and do not have a refrigerated cabinet. More common designs use a welded assembly of exterior panels with insulation and liner inserts.

Materials used on exteriors and interiors are stainless steel, painted steel, aluminum-coated steel, aluminum, and vinyl-clad steel with wood grain or other patterns. Materials must (1) match or blend with that used on nearby equipment; (2) be easy to keep clean; (3) not be discolored or etched by common cleaning materials; (4) be strong enough to resist denting, scratching, and abrasion; and (5) provide the necessary frame strength. The material chosen by an individual purchaser depends a great deal on layout and budget.

Shelves are standard interior accessories, and are usually adjustable and furnished three or four per full-height section.

ENERGY EFFICIENCY OPPORTUNITIES

Products discussed in this section use different components and design strategies. The following is a list of options that are or can be used in these products. Some of the options are mature and tested in the industry, whereas others are emerging technologies. Designers must balance energy savings against customer requirements, manufacturing cost, system performance, reliability, and maintenance costs. Several of these options can be applied to all refrigeration systems; others apply only to specific types of equipment. The following list defines some of the energy efficiency measures that may be implemented. Table 1 shows applicability to the equipment discussed in this chapter.

Table 1 Applicability of Energy-Efficiency Opportunities to Refrigeration Equipment

	Roll-Ins/ Reach-Ins	Walk-Ins	Vending Machines	Ice Machines	Preparation Tables
High-efficiency compressors with capacity modulation capability	X	X	X	X	X
High-efficiency evaporator and condenser coils	X	X	X	X	X
Condenser fan and evaporator fan ECM	X	X	X	X	X
Auto door-closers		X			
Compact fluorescent lights		X			
Liquid-to-suction heat exchangers	X	X	X	X	
Insulation for bare suction lines	X	X			
Expansion valve with superheat control	X	X			
Efficient defrost	X	X			
Strip curtains or plastic doors		X			
Occupancy sensors		X			
Evaporator fan controller		X (Coolers only)			
High-efficiency lighting system			X		
Improved airflow through refrigerated cabinet			X		X
Airtight cabinet construction			X		X
Improved insulation		X	X		X
Lids					X

- **High-efficiency compressors with capacity modulation capability** enable the variable-speed-driven compressor to match capacity with the varying cooling load.
- **High-efficiency evaporator and condenser coils** with increased surface area and conductivity can transfer heat with the air more effectively.
- **Condenser fan and evaporator fan electronically commutated motors (ECMs)** use less power than shaded-pole motors. They also can incorporate variable-speed controllers.
- **Auto door-closers** ensure that the door is pulled securely shut when it is within 1 in. of full closure, thereby reducing air infiltration.
- **Compact fluorescent lights (CFLs)** can replace the incandescent bulb, reducing energy consumption and heat production. CFLs can now operate in cooler/freezer temperature ranges.
- **Liquid-to-suction heat exchangers** allow suction gas leaving the evaporator to absorb heat from liquid refrigerant entering the evaporator, increasing the subcooling and cooling capacity of the system.
- **Insulation for bare suction lines** reduce system losses.
- **Expansion valve with superheat control** reduces the mass flow rate of refrigerant as a function of superheat, thereby reducing compressor power under low load.
- **Efficient defrost** methods, such as hot gas or cool gas, remove ice from the coil in a comparatively short period of time while adding little heat to the refrigerated space. Defrost should be controlled with temperature termination so that compressor off-time lasts only as long as necessary to melt the ice.
- **Strip curtains** or **plastic doors** provide a barrier against ambient air infiltration when the walk-in cooler/freezer door is open.
- **Occupancy sensors** can be installed to turn interior lights on and off as a function of occupancy and traffic. This also reduces a source of heat inside the cooler/freezer.
- An **evaporator fan controller for walk-in coolers** reduces airflow of evaporator fans in medium-temperature walk-in coolers when compressor(s) cycle off and there is no refrigerant flow through the evaporator. They should not be used if (1) the compressor runs all the time with high duty cycle, (2) the evaporator fan does not run at full speed all the time, (3) the evaporator fan motor runs on polyphase power, (4) the evaporator fan motor is not shaded pole, or (5) the evaporator does not use off-cycle or time-off defrost.
- **High-efficiency lighting systems** include electronic ballast and efficient light bulbs.
- **Improved airflow through refrigerated cabinets** can reduce the input energy required by the evaporator fan and promote uniform cooling of products inside the cabinet.
- **Airtight cabinet construction** eliminates infiltration of warm and moist air.
- **Improved insulation** reduces conductive heat transfer through the walls of the refrigerated cabinet.
- **Closing lids** on refrigerated prep tables during non-use periods substantially reduces energy use.

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