Placing the evaporator in heat exchange relation to the beverage coil has the advantage of adding the refrigeration system capacity to that of the latent storage and aids in distribution of heat transfer, but the critical temperature control to prevent freezing the beverage must be carefully considered.

Carbonation and freezing points vary with different flavors. Where beverages of two or more flavors are dispensed in one machine, the temperature must be adjusted for the one with the highest freezing temperature.

Icemakers

A recent development is the use of icemakers as an integral part of cup-type drink vendors to provide approximately 2 oz of ice in each drink. These icemakers are generally compact systems utilizing a $\frac{1}{4}$ or $\frac{1}{3}$ hp compressor, and have a capacity of 100–200 lb of ice per day. Some units re-freeze the melt water, while others have a heater which operates in conjunction with the main condenser fan of the vendor to evaporate the melt water.

Coffee Vendors

Refrigeration serves an important function in coin-operated coffee machines for preserving fresh cream when used, or in some cases for holding a liquid coffee concentrate at the proper temperature. The amount of refrigeration required is small for even the largest machines of 800 to 1000 cup capacities. Commercially available 1/12 hp compressors provide more capacity than is needed to cool and keep the 2 to 4 quarts of cream stored. Cleanliness and sanitation are primary requirements. Cream in the metering tube must be kept well below 50 F, which may require that the metering valve be located in the insulated compartment with the cream container, and provided with a means of flushing the transfer tube leading to the cup during or after each serving. Temperature control must prevent freezing of the cream in the storage container, metering valve, or transfer tube. Since 4 percent butterfat milk freezes[1] at approximately 31.9 F and half-and-half cream at 32 F, storage at 34 to 37 F is desirable for good storage life.

Plate evaporators, while economical, accent the temperature control problem where the cream container rests on or near the plate. Forced-air circulation to promote natural convection should be considered. The insulated cooler located within the coffee machine may have temperatures at its outer walls of 50 F deg above ambient temperature due to the hot water and various heaters in the machine. Also present are small quantities of escaping steam which require vapor sealing of the outer envelope around the insulation.

Refrigerated Food Vendors

Milk in waxed paper cartons is being vended in sizes from $\frac{1}{2}$ pint to $\frac{1}{2}$ gal. Machine capacities range from about 70 to 300 cartons. The variety of available carton shapes and sizes requires a variable or convertible vending mechanism and changes the air spaces between containers. Some containers are block-shaped and positioned so there is little space for air movement to accomplish cooling. Cooling can be helped in this situation by means of conduction through an adjacent metal plate. The waxed paper container does not seem to reduce cooling rates as compared to glass-bottled beverages. Common practice is to circulate air continuously in the milk cooler using a finned-tube evaporator. The usual holding temperature is 35 F and as milk must be delivered not exceeding 50 F to meet USDA Sanitation Code,[2] there is only a small pull-down load for the refrigeration. Thus the system can be sized closer to the heat-leak load of the cabinet than in most applications. Ease of washing the interior is of primary importance in the design.

Chilled foods of all descriptions, when packed in suitable cartons, may be vended in the same manner as milk cartons. The temperatures required are approximately the same. The refrigeration capacity required usually is slightly greater where foods at room temperature are placed in the machine. However, the total heat content of salads, cottage cheese and other lunch items may be considerably less than the total for a load of 50 F milk.

Food items requiring temperatures below 32 F make it necessary to provide adequate defrosting for vendors using finned coils and forced-air circulation.

Ice cream vendors usually use plate type evaporators with space for frost buildup. In addition to the usual precautions of sealing moisture out of the insulated walls, it is necessary to limit the moisture accumulating on the interior, especially during loading of merchandise in the machine. Baffles and inner doors can be used to reduce air movement into the cold machine. A control should provide a selection of temperatures from − 10 to 0 F.

APPLICABLE STANDARDS

A uniform procedure has been developed for testing refrigeration systems, determining performance data, and rating bottle capacity for self-contained, mechanically-refrigerated bottled beverage coolers and vendors.[3]

A standard for vending machines has been prepared by the Underwriters' Laboratories.[4]

Approval by the Canadian Standards Association is required for machines sold in Canada.

The United States Department of Health, Education and Welfare adopted a Sanitation Ordinance and Code in 1958 which specifically applies to vending of foods and beverages.[2] While compliance is voluntary except at government installations, many municipal and county health agencies are requiring food vending operators to meet this code. It requires screens to verminproof a machine, a manual-reset thermostat to stop all vending if the food temperature exceeds 50 F, and other cleanliness provisions.

Many of the larger cities have health codes of their own which should be considered on an individual basis.

The National Automatic Merchandising Association (Chicago, Illinois) has established standards of sanitation, safety, design, and construction of various vendors. This work was done in cooperation with personnel of Michigan State University and Indiana State University.

The National Sanitation Foundation, Ann Arbor, Michigan, also has a vending code and evaluation procedure.

REFERENCES

1 Unpublished laboratory data (Tests PDE 57 and ME 1150, Vendo Company, Kansas City, Mo., 1958).

2 *Sanitation Ordinance and Code for Vending of Foods and Beverages* (U. S. Dept. of Health, Education and Welfare, Washington, D. C., Public Health Service Publication 546, 1957).

3 *ASHRAE Standard Methods of Rating and Testing Bottled Beverage Coolers* (ASHRAE Standard 32-57, 1957).

4 *Standards for Vending Machines* (Standard UL 541, Underwriters' Laboratories, Inc., Chicago, 1958).

CHAPTER 63

AUTOMATIC ICEMAKERS

Ice Cube, Flaked Ice, and Compressed Ice Machines; Performance Characteristics for Clear-Cube, White-Flake, Clear-Chip, and Clear-Flake Machines; Design Requirements; System Design; Refrigeration Systems; Water Systems for Icemaking and Condensing; Electrical System; Storage Bins; Pitfalls in Equipment Design

THIS chapter deals with unitary commercial icemaking equipment of the type that automatically freezes and stores its own product. Designed for use in hotels, restaurants, bars, hospitals, produce-markets and the like, these machines can be located close to the point where the ice is to be used.

The machines herein described make ice in the form of cubes, flakes, chips, chunks, and odd-shaped but uniform small bodies, depending on the freezing and harvesting method used. The product may be clear, white, or translucent, depending on the method of freezing. For purposes of discussion, apparatus will be classified as (1) ice cube machines producing clear ice, or white ice, and (2) iceflake machines producing clear ice, or white ice, with the understanding that the former makes ice bodies of substantial thickness ($\frac{1}{8}$ in. minimum), and uniform appearance, while the flake machines make thin ice of predetermined uniform thickness ($\frac{1}{16}$ to $\frac{1}{8}$ in.) but of random size in other dimensions. The capacities under discussion in this chapter will be from 35 lb of ice per day to 2000 lb per day for ice cube machines, and from 100 lb per day to 60,000 lb per day for iceflake machines.

ICE CUBE MACHINES FOR CLEAR ICE

The principles involved in making clear ice bodies have been known and used for decades. For instance, in 1897 a British patent was granted on an apparatus which produced clear ice cubes in submerged refrigerated cells which were partitioned off by poor heat conductors. Agitation of the water was provided to keep the ice clear as it formed, and harvesting of the cubes was accomplished by circulating a warm fluid under the cells until the ice melted loose and floated to the surface of the tank. Eventually engineers combined this freezing method with modern materials, controls and components to produce a fully automatic icecube maker.

Clear ice cube makers are classified as: (1) tube machines, (2) cell machines, (3) plate machines, (4) rod machines, or (5) channel machines. All depend on water flow or agitation to give clarity to the ice.

The *tube type* machine makes long cylinders of clear ice in vertical, refrigerated brass tubes, with a central hole left in the ice by flowing water. At the proper time, freezing is discontinued, and the columns of ice are melted loose and then mechanically cut into individual, short pieces of ice. This machine, like many others made today, has an optional device for crushing the cubes as they drop to the storage bin.

Another cube machine also makes ice in vertical brass tubes. However, square sticks are formed, each with a central hole left by flowing water. Harvesting of the ice and cutting it into short lengths is done by hot-gas melting and mechanical chopping.

A third cube machine of the tube type forms separate ice bodies in square, vertical stainless steel tubes which are banded at uniformly spaced intervals with copper heat conductors, which in turn are refrigerated. Water flowing down the inside of the tubes turns to ice in the region of the bands, thereby producing clear ice cubes with an hour-glass-shaped hole through the center. Hot gas harvesting is employed, and the cubes fall by gravity to a storage bin, just as in the two previously described tube machines.

Another type of automatic icemaker produces clear, solid pieces of ice in the shape of rectangular lenses having one flat side and a curved side, with square ends. These ice bodies are made in square, vertical, stainless steel tubes to which are bonded spaced refrigerant tubes on two opposed sides. Water flows down the inside walls of the tubes, forming ice at the refrigerated portions. Suitable controls terminate the freezing operation and thaw the ice loose.

A machine that deserves mention, even though it is no longer produced, is the type in which ice was formed in vertical, cylindrical tubes and kept clear by the action of air that bubbled up through the water. When the rods of ice were frozen solid, hot gas melted them loose, air pressure forced them up against a breaker plate, and the resulting short pieces of ice tumbled into a storage bin. A variation of this principle utilizes a refrigerated, coiled tube, about $\frac{5}{8}$ in. in diameter, through which water flows and freezes. Upon closure of the hole in the ice, hot gas is sent through the evaporator to free the ice which is then forced out by water pressure and broken into short pieces by an angular deflector.

Cell-type, clear-cube machines form ice as individual pieces which are then harvested and stored automatically. Some of these machines produce ice that closely resembles the *ice company* cubes that are cut from large cakes of ice.

One type of solid-cube machine makes clear, solid icecubes in a refrigerated chamber partitioned into cubical cells mounted with the open end down. A plastic sealing plate, through which water is introduced and allowed to flow away from the cells, forms the bottom side of the enclosures. On completion of the freezing cycle, the controls shift to a hot-gas defrosting operation, the hinged sealing plate is forced away from the ice to which it had frozen, and the whole mass of cubes drops onto the plate and slides into the storage bin. This machine is a refinement of a similar icemaker built during the late 1940's.

One cell type has inverted refrigerated cylindrical cups which are sprayed with water. A timer ends the freezing cycle and causes pre-heated water to flow over the outside of the cups to melt the cubes loose and send them to the storage bin below.

Another inverted-cell machine sprays water up into square refrigerated cups, thereby causing clear cubes of ice to form. They are thawed loose by hot gas and dropped into the storage bin.

Plate-type icecube machines make ice on refrigerated, flat plates. Water flows over inclined flat plates, thereby building up a sheet of ice from $\frac{1}{4}$ in. to 1 in. thick. Automatic controls cause the ice sheet to melt loose and slide off the plate onto a heated grid for cutting into cubes. In one instance, electrically

The general responsibility for this chapter is assigned to TC 8.4, Ice Makers.