so that the spaces around and between the bottles for air circulation are predetermined. High velocities over the bottles can be obtained by concentrating the chosen quantity of air over fewer bottles. Air quantities of 1.5 cfm per bottle to be cooled at about 150 fpm velocity have been found satisfactory for nominal cooling rates. The use of 2.5 cfm per bottle at a velocity of approximately 250 fpm resulted in an increased cooling rate of nearly 40 percent.[1]

Static-pressure differences across the fan blade seldom exceed 0.1 in. of water in the usual bottle vendor. Accurate static pressure readings are difficult to obtain in most vendors because of the turbulence in the confined spaces used for air passageways. Planning for ample areas for air passageways in designing the unit will improve performance and efficiency. Adequate space for the desired size of fan will allow use of conventional fan motors of the 1400–1500 rpm variety, whereas a small fan space may require 2800–3000 rpm motors. Since the power required increases as the cube of the fan speed, unwanted heat will be the penalty for not allowing room for the desired fan and motor. Shaded-pole motors delivering 1/80 hp (4 to 9 watts output) or less have been satisfactory.

Condensate from the evaporator usually drains from the cooled compartment into a container or pan. A trap in the drain line aids in preventing air and moisture from entering the cabinet through the drain. Provision must be made for the occasional breakage of a bottle and, therefore, the pan or container is usually removable for cleaning. Evaporative surfaces may be provided to dispose of the normal condensate water. Sufficient evaporative capacity should be provided to dispose of condensate collected during operation at 90 F dry-bulb temperature and 90 percent relative humidity.

Equipment Evaluation

The following considerations will aid in evaluating beverage coolers:

1. The cooling rate should be balanced with the anticipated vending rates and load schedules.
2. The time required for cold bottles to become available after reloading. Also, whether or not warm bottles will be vended immediately after reloading.
3. Temperature of product as vended should be uniform.
4. The product temperature should not vary excessively with changes in ambient temperature.
5. Refrigeration equipment should be readily accessible.
6. The ratio of evaporator and condenser volumes should be satisfactory for operation in the entire range of ambient temperatures anticipated in a particular location.
7. Cabinet and exterior tubing should not sweat excessively during periods of high relative humidity.
8. Cost of operation.
9. The unit should be capable of operating satisfactorily at reduced voltages which may be encountered.
10. Evaporator defrosting and condensate disposal should be satisfactory when the unit is operated during periods of high relative humidity.
11. Electrical components should meet the requirements of Underwriters' Laboratories.

REFRIGERATION CALCULATIONS

The total load of a vendor is the sum of the product load and the heat gain through the cabinet. Conduction values calculated for the walls may be increased 50 to 100 percent to allow for losses across breaker strips, gaskets, etc. Heat to be removed from bottles of beverage may be calculated by considering the glass and beverage separately. The specific heat of glass is 0.19, while the specific heat of the beverage may be taken as unity.

The product load for cooling bottled beverages is:

$$Q_b = \frac{(t_1 - t_2)(W_g c_g + W_p c_p)N}{\tau}$$

where

Q_b = average load for cooling bottles and beverage, Btu per hour.
t_1 = initial temperature of bottles, Fahrenheit.
t_2 = final temperature of bottles, Fahrenheit.
W_g = weight of each bottle, pounds.
W_p = weight of product in each bottle, pounds.
c_g = specific heat of glass, Btu per (pound) (Fahrenheit degree).
c_p = specific heat of product, Btu per (pound) (Fahrenheit degree).
N = number of bottles.
τ = time, hours.

Calculation of the load required to cool bottled beverages is illustrated by *Example 1*.

Example 1: Determine the load required to cool 100 bottles, each containing 8 fluid oz of beverage (specific gravity = 1.0) from 90 F to 30 F in 3 hr. Each bottle weighs 1 lb when empty.

Solution: The weight of the beverage in each bottle is

$$\frac{8}{4 \times 32} \times 8.34 \times 1.0 = 0.52 \text{ lb.}$$

$$Q_b = \frac{(90 - 30)(1 \times 0.14 + 0.52 \times 1)100}{3} = 1320 \text{ Btuh}$$

Heat leakage through the cabinet walls can be determined, using the appropriate conductivity and thickness of the insulation, cabinet wall area, and temperature difference. Additional losses through door seals and for other leakage must be approximated. For a vendor such as used in *Example 1*, the total heat leakage would be approximately 300 Btuh. Thus, total cooling load for the vendor of *Example 1* would be 1320 + 300 = 1620 Btuh.

Where zone cooling is employed in the cabinet, the cooling load may be reduced considerably. Air may be directed so that cooling is effected in two or three zones. Then the average bottle cooling load is reduced by an amount proportional to the amount of cooling done in each zone.

Water-cooling coils with drinking fountains located on the side of the vendor are popular in some areas. This additional refrigeration load is not usually considered in the design and can affect bottle cooling rate, depending on the water usage. The water-cooling possibilities of such an arrangement usually are quite limited.

CANNED BEVERAGE VENDORS

These units, also called can vendors, are similar to bottle vendors and are often adaptations. Because the can (usually 8 to 12 oz in capacity) is a compact container, the total number of cans in a given cabinet is often nearly double the number of bottles which could be vended. This has some effect on the refrigeration load. Although the specific heat of steel is less than glass (0.11 to 0.19), the conductivity of steel is higher than glass. Therefore the initial heat rejection by the refrigeration system will have to be much greater for the can vendor than for a comparable bottle vendor. This difference, while technically significant, has not been noted by any applicable agencies, and tests used for can vendors are the same as those for bottle vendors.

OTHER REFRIGERATED VENDING MACHINES

Post-Mix Vendors

The term *Post-mix Vendor* applies to a bulk-type, carbonated-drink vending machine, which is connected directly to the city water or some other source of potable water, and

contains bulk syrup and means for carbonating water. The actual mixing of the drink is achieved in the cup, in that both water and syrup are measured and dispensed through independent hydraulic circuits. The refrigeration of the water in these machines has been accomplished by various methods.

One method used for this system has been to meter the mixing water into a large water reservoir tank which is at atmospheric pressure. This reservoir is refrigerated to maintain drinking temperature, or the water reservoir may contain an ice bank for use during periods of peak vending.

The second method is similar to the first method except the potable water is contained within a coil of tubing, and the water in the tank is used as a cooling medium. Control of the ice bank size may be more critical in this system.

The third method is to use a cast aluminum direct expansion heat exchanger to cool the potable water as it passes through the coil.

The occasional drink vended from the machine should be as cold as drinks served on a continuous basis. In order to get a cold casual drink, it is necessary that both the water and syrup be refrigerated before it is delivered into the cup. The syrup reservoirs need not be refrigerated, but storage life of the syrup may be extended if the syrup is kept cool.

Carbonation is usually accomplished by the use of standard carbonators which carbonates the water by introducing a controlled amount of CO_2 gas into the potable water supply. The quantity of water that may be carbonated at one time can vary from one drink to several drinks. This incoming potable water should be filtered to remove the chlorine and impurities to insure proper carbonation and provide a good tasting drink. A properly designed dispensing system must be used to minimize loss of carbonation while dispensing the carbonated water.

The flow of both water and syrup is controlled through the use of a variable orifice type of solenoid valve, although in some machines the syrup is supplied to the cup through the use of a positive displacement pump. However, the cost and complexity of such a system is greater than for the metering type solenoid valve. When the solenoid valve system is used, the syrup-storage tanks must be pressurized to provide motive force for the dispensing of the syrup.

The size of post-mix cup vendors is generally controlled by the cup capacity of the unit, and most operators use the number of cups dispensed as a cross-check on the amount of money in the coin box. The use of cups as a regulating means also provides a simple method for determining when the machine needs refilling. Post-mix vendors have been readily acceptable in the field in locations where the use of bottles is impractical and where bottle loss or damage has been found to be excessive. They also provide a high capacity machine with respect to product storage. However, the service on such equipment must be frequent to assure proper sanitation.

Pre-Mix Vendors

The term pre-mix is derived from the fact that the beverage is mixed and packaged in bulk quantities in sanitary sealed containers before delivery to the vending machine. The machine then cools the already mixed and carbonated beverage and vends a measured quantity into a cup. Control of the quality of the mix is the primary advantage of this type of vendor. The bottling plant fills stainless steel tanks containing 300 or 600 oz for distribution. An approved polyethylene hose is used to connect the tanks to the machine. It usually has stainless steel braid reinforcement and sanitary shut-off valves which close when the connection is broken. The cooling coil carrying the beverage is of an approved stainless steel and all joints are welded. Tanks are usually connected in series with a regulated carbon dioxide pressure connected to the tanks to force the liquid through the circuit as in Fig. 3.

The number of tanks which can be connected in this manner is limited by the foaming characteristics of the beverage. The more tanks connected, the greater will be the pressure required to force the beverage out at the vending valve at a flow rate suitable for the particular metering system used. As pressure is increased, the beverage in all tanks absorbs more carbon dioxide. A typical beverage containing more than 3.7 volumes of carbon dioxide will foam excessively after passing through the uniform flow control and vending valve into the cup. The machine must also be capable of vending the first drink cold after long periods, even when the unit is standing in the sun. Various size cups (7, 9 and 10 fluid oz) can be dispensed from devices currently available that will store up to 1000 cups and drop the cup into position when triggered.

A typical dispensing cycle might be explained briefly as follows (see Fig. 3). Gas entering the gas port of the product tank keeps the product in the tank under pressure. When the dispensing valve is open, this pressure forces the product up through the dip tube, through the coupling tubing and into the next product tank. This process continues until the product is forced out of the last tank, through a cooling mechanism, and then through the tubing to the valve. The dispensing valve can be opened automatically or manually to deliver the product into a cup.

Current practice is to cool the beverage after it leaves the tank by means of a *flash cooler*, consisting of a sanitary coil immersed in a eutectic solution or water, located adjacent to refrigerant coils. An ice bank is usually provided for additional capacity for use during periods of peak vending. The rate of heat removal required from the walls of the beverage coil during peak flow periods is so great that methods of conducting this heat to the ice or eutectic may be employed. Various types of extended surfaces are used to overcome the resistance of the water film adjacent to the beverage coil.

The evaporator coil is placed in such relation to the beverage coil that the water or solution will be frozen in the position best suited. If the evaporator is located too far from the beverage coil, lag in rebuilding the latent-heat bank will occur, while if the beverage and evaporator tubes are too closely in contact, freezing of the beverage can occur. A dependable control must be used to keep the evaporator temperature above the beverage freezing point. The freezing point of different brands of beverages varies and is affected by the amount of carbonation. The freezing points ordinarily encountered range from 31 to 27 F. The amount of ice needed for cooling a given amount of beverage can be calculated from the dispensing rate required.

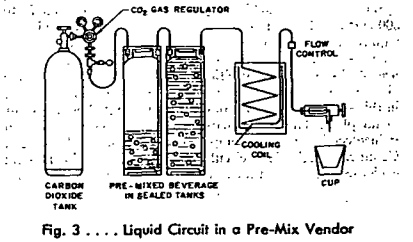

Fig. 3 . . . . Liquid Circuit in a Pre-Mix Vendor