the water. In some plants this system has been adapted to brine already cooled in some other part of the plant for another purpose. Then the same refrigeration system may be used for more than one unit. The water being cooled is generally led through a closed pipe immersed in the circulating brine.

Recently there have been ingenious combinations made of the cooling surfaces built directly into the carbonator units. Here the surfaces over which the water is run present a large area to the carbon dioxide atmosphere. The surface is cooled, thereby doing double service. These designs are, at present, variations of the descending film type of cooler.

These coolers are nearly all of special design whose capacity for cooling water, based on previous performance, is known and specified by the manufacturer. Hence, the capacity of cooling surface or units is best based on manufacturer's listing.

Still another type of water cooler is the *U-type*, having a series of pipes carrying the refrigerant, immersed in a shell containing water. The pipes are bent in U-form horizontally, to provide a smooth passage for the halocarbon refrigerant.

Both of these latter types may operate flooded with the refrigerant in the shell, or as direct expansion chillers with the refrigerant inside the tubes.

Sanitation

In all of these types the factor of prime importance is keeping the water free from contamination, either with foreign substance or organisms picked up from the unit or from metals dissolved in transit. For these reasons, the units are designed for ease of cleaning, freedom from water stagnation and built of corrosion-resisting non-toxic metal (preferably tinned or of resistant base metal such as stainless steel).

Cleaning is necessary to prevent any possibility of growth of organisms in the unit which would tend to contaminate the water passing through it. Water stagnation should be prevented for the same reason. Likewise, if a small amount of water is contained in the unit at any time, due to small reservoir tanks or pumps, the unit can be more readily drained and cleaned.

The smaller units for cooling can usually be set up in any place desired in the plant, while the larger units for plants of greater capacity may actually be built into a refrigerator room. With these smaller units the water being cooled should be protected from contamination by having a cover over the cooling surfaces and reservoirs. This prevents air circulation from the outside or accidental contamination by workmen, insects or dust. Wherever possible, all parts should be of metal, for wherever wood or organic material is in contact with the water there is greater possibility for growth of microorganisms. With the units built in a refrigerator room, the same precautions should be observed. If it is desirable to demonstrate this room in plant tours, inspection windows should be provided rather than allowing visitors to enter the room. It has been proven wise to keep the coolers locked to prevent tampering.

The refrigerants commonly used in these units vary with the design and size and may be ammonia, halogenated hydrocarbons, methyl chloride and others. The types of compressors vary also with the particular unit in question, and, as with other commercial units beginning at several tons capacity, they vary from the small high speed units to the larger heavy duty ones.

Small plants commonly use main or well water for condensers. Water usage restrictions have encouraged the use of cooling towers and definite economy has resulted in larger installations. Increased economy can be gained by employing used or warmed condenser water for some manufacturing processes such as rinsing jets on the bottle washing machines. Care must be taken that this water is in no way contaminated with grease, oil or other substance which might in any way interfere with the cleanliness of the bottle.

Water Temperatures

The temperature to which water must be cooled depends on the type of bottle filling machinery used. They may be divided into three general classes: (1) those which use water at supply temperature or less, (2) those which operate with water at 45 to 55 F, and (3) those which require water of 40 F or lower.

If filling machines use water at the temperature of the water supply, they must hold a pressure against the carbonated water continuously during the filling process and the crowning of the bottle. It is claimed for this system that extremely stable carbonated water is not needed, since the pressure maintained prevents loss of carbonation. This filler will nevertheless operate at lower filling pressures if the water is cooled, and a more uniform product is likely to result. The exact temperature to which the water should be cooled in this instance depends on the wishes of the particular plant.

Those operating with water at temperatures in the range of 45 to 55 F are the intermediate type. Due to their valve design, they can release the pressure on the filled bottles before crowning, without losing carbonation. They have proved fully successful and can be made to operate with somewhat warmer water if necessary.

The third class of filler requires a very stable carbonated water, achieved by cooling the water to 40 F or lower. Only with such water temperature can the best results be obtained; with warmer water, irregularity of the finished product is likely to occur.

In every installation it is important to determine the type of filling equipment first.

Refrigeration Load

The refrigeration load is determined by the amount of water being cooled per unit of time. Since most of the cooling units are of the instantaneous type, there is little cold water reserve and they must be able to continuously furnish the desired output of cold water without relying on storage reserve.

To determine the water demand of the given equipment, the maximum fluid output of the filler should be determined. This is usually found when filling quart bottles with carbonated water. Under these circumstances the commonly used commercial units will require from 2 to 16 gpm of water, depending on their size and design. Where several units of the same size are installed they will require multiples of the basic water demand.

Knowing the water temperature from the supply pipe or system before cooling, the temperature to which the water is to be cooled, and the water demand in gpm, the tons of refrigeration can be determined by the following approximation:

$$q_t = \frac{W(t_s - t_c)}{24} \qquad (2)$$

where

q_t = cooling load, tons of refrigeration.
W = water flow rate, gpm.
t_s = supply water temperature, Fahrenheit.
t_c = cold water temperature, Fahrenheit.

Thus to cool 16 gpm of water from 70 to 45 F, the refrigeration load, in tons, is $16\,(70-45)/24 = 16.66$ tons.

In the computation of the load, one of the most troublesome values to determine accurately will be the highest temperature the main water can be expected to reach. This usually occurs in the hottest summer periods. Moreover, one must allow for additional warming of the water going through water filters or treatment equipment, in the bottling plant. If the refrigeration equipment is to deliver uniformly cooled water of proper temperature under maximum demand, an ample figure must be allowed.

The extent to which water will rise in temperature as it progresses in the filling equipment depends on the insulation of the equipment and pipes. Newer types of apparatus are well insulated. In poor installations, or those in which the insulation has become wet or damaged, the gain may reach and even exceed 10 F deg. Therefore, this factor can best be judged by the individual plant installation.

Size of Plant and Area of Distribution

The output of various plants depends basically on the bottle filling capacity of their machinery. The smallest individual units requiring a large amount of manual manipulation will turn out approximately 30 cases of 24 bottles each of splits (approximately half pint capacity) per hour. Intermediate sizes, semi-automatic, will turn out about 60 cases per hour; fully automatic machines begin at approximately 75 cases per hour and go through several increases in size on to the largest units which approach 1200 cases per hour.

The operation of these machines, which also determines the demand on refrigeration machinery, is usually not to exceed eight hours per day. But, often it is found that in cold weather when the demand for bottled carbonated beverages is less, operation may be only on intermittent days and, conversely, in extremely hot weather it may be necessary to operate several eight-hour shifts a day to meet the demand.

On this above case output, an arbitrary classification of plants may be those with the smallest type of equipment which will put out under 150,000 cases per year; intermediate may be in the range of 150,000 to 500,000 cases per year; while the larger equipment and large plants may be over 500,000 or more cases per year, the latter requiring installation of multiple bottle filling equipment lines.

The usual area of distribution of the finished beverages is within the metropolitan area of the city in which the plant is located although some plants have built up such a reputation for their goods that they may ship to warehouses up to several hundred miles distant, from which local distribution is then made. A few nationally known products are shipped long distances from the producing plant for specialized markets. The transportation of the beverages does not require refrigeration, although it is advisable to protect the bottled goods against excessive temperature or direct sunlight. The beverage at the point of consumption is customarily cooled to temperatures in the neighborhood of 40 F for a maximum refreshing effect.

Sirup Cooling

In some plants, cooling of the prepared sirups has been found to promote more uniform beverages. This is particularly important in the type of filling units in which the washed bottle is first given an amount of sirup called a *throw*, to which is added about five times the volume of carbonated water. When this sirup is extremely warm, it causes excessive bubbling and gas loss from the beverage when the bottle is opened to the atmosphere before crowning. In these instances cooling units, most often of the Baudelot or tube-in-shell type, are used to bring the sirup to 50 F or lower. The original sirup may be at the temperature of the storage area or may even be higher if the sirup is prepared by heating.

The cooling load from sirups can be estimated similarly to that of water, as given by the above approximation. It must be remembered that the sirups commonly used are of fairly high density, in the range of 27 to 34 Baume (50 to 65 percent sugar by weight) and at about 60 F may have very high viscosities (30 to 50 centipoises or more), which will make heat exchange from these sirups much slower than that to be expected when using water in a given piece of equipment. Likewise, the cooling surfaces must be readily cleaned after use so that there can be no opportunity for residues of sirups to remain and allow the development of spoilage organisms which will contaminate subsequent sirups.

Since in most filling equipment the sirup and water are not completely mixed, it is necessary either to invert the bottles by hand to mix the heavier sirup with water, or to use mechanical mixing apparatus which will invert the bottle a number of times, giving complete blending into the finished product. Because virtually none of the output of the plant is consumed directly from the filling machine, the resulting temperature of the finished beverage due to the heat gain from the bottles and sirup, is not important so long as the carbonated water remains stable during filling. No refrigeration is needed on the goods after bottling and they are allowed to warm up to room temperature in storage not being again cooled until just before consumption.

Low Pressure Liquid Carbon Dioxide Storage

Carbon dioxide for carbonating water and beverages has been furnished for many years compressed and liquefied in steel cylinders designed for pressures up to 1500 psi. Larger users have utilized solid carbon dioxide which can be shipped without the extra weight of cylinders, employing converters consisting of steel pressure vessels with large access hatches designed for gas equilibrium pressures in the neighborhood of 1000 psi at room temperatures. However, in metropolitan areas it is possible to get liquefied carbon dioxide delivered to the plant in trucks from which the liquid can be piped to large storage-converter tanks of special design and equipped with mechanical refrigeration. The typical unit of this type is maintained at internal temperatures not in excess of 0 F so that the equilibrium pressure of carbon dioxide does not exceed 300 psi. By this system very large storage capacity can be obtained with attendant savings and the storage tanks need not be built for excessively high pressures. Full control equipment is provided for the refrigeration, and relief safety valves of ample capacity prevent excess pressure build up. The employment of the refrigerating effects of the gasifying carbon dioxide as the sole means of temperature maintenance has proved to be more expensive than properly designed mechanical refrigeration.

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