CHAPTER 33

ICE MANUFACTURE

MOST commercial ice production is done with ice makers that produce three basic types of fragmentary ice, which vary according to the type and size required for a particular application. The basic types of fragmentary ice are flake, tubular, and plate. Among the many applications for manufactured ice are

- Processing: Fish, meat, poultry, dairy, bakery products, and hydrocooling
- Storage and transportation: Fish, meat, poultry, and dairy products
- Manufacturing: Chemicals and pharmaceuticals
- Others: Retail consumer ice, concrete mixing and curing, and off-peak thermal storage

ICE MAKERS

Flake Ice

Flake ice is produced by applying water to the inside or outside of a refrigerated drum or to the outside of a refrigerated disk. The drum is either vertical or horizontal and may be either stationary or fixed. The disk is vertical and rotates about a horizontal axis.

Ice removal devices fracture the thin layer of ice produced on the freezing surface of the ice maker, breaking it free from the freezing surface and allowing it to fall into an ice bin, which is generally located below the ice maker.

The thickness of the ice produced by flake ice machines can be varied by adjusting the speed of the rotating part of the machine, varying evaporator temperature, or regulating the water flow on the freezing surface. Flake ice is produced continuously, unlike tubular and plate ice, which are produced in an intermittent cycle or harvest operation. The resulting thickness ranges from 0.04 to 0.18 in. A continuous operation (without a harvest cycle) requires less refrigeration capacity to produce a ton of ice than any other type of ice manufacture with similar makeup water and evaporating temperatures. The exact amount of refrigeration required varies by the type and design of the flake ice machine. Typical flake ice machines are shown in Figures 1 and 2.

All water used by flake ice machines is converted into ice; therefore, there is no waste or spillage. Flake ice makers are usually operated at a lower evaporating temperature than tube or plate ice makers, and the ice is colder when it is removed from the ice-making surface. The surface of flake ice is not wetted by thawing during removal from the freezing surface, as is common with other types of ice. Because it is produced at a colder temperature, flake ice is most adaptable to automated storage, particularly when low-temperature ice is desired.

The rapid freezing of water on the freezing surface entrains air in the flake ice, giving it an opaque appearance. For this reason, flake ice is not commonly used for applications where clear ice is important. Where rapid cooling is important, such as in chemical processing and concrete cooling, flake ice is ideal because the flakes present the maximum amount of cooling surface for a given amount of ice.

When used as ingredient ice in sausage making or other food grinding and mixing, flake ice provides rapid cooling while minimizing mechanical damage to other ingredients and wear on mixing/cutting blades.

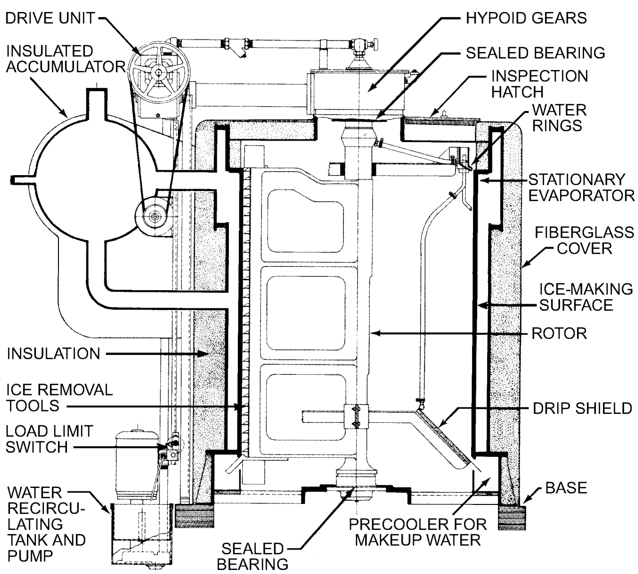

Fig. 1 Flake Ice Maker

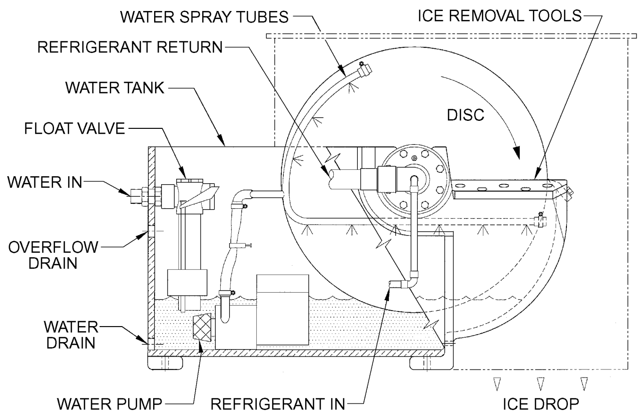

Fig. 2 Disk Flake Ice Maker

The preparation of this chapter is assigned to TC 10.2, Automatic Icemaking Plants and Skating Rinks.

Some flake ice machines can produce salty ice from seawater. These are particularly useful in shipboard applications. Other flake ice machines require adding trace amounts of salt to the makeup water to enhance the release of ice from the refrigerated surface. In rare cases, the presence of salt in the finished product may be objectionable.

Tubular Ice

Tubular ice is produced by freezing a falling film of water either on the outside of a tube with evaporating refrigerant on the inside, or on the inside of tubes surrounded by evaporating refrigerant on the outside.

Outside Tube. When ice is produced on the outside of a tube, the freezing cycle is normally from 8 to 15 min, with the final ice thickness from 0.2 to over 0.5 in. following the curvature of the tube. The refrigerant temperature inside the tube continually drops from an initial suction temperature of about 25°F to the terminal suction temperature in the range of 10 to –15°F. At the end of the freezing cycle, the circulating water is shut off, and hot discharge gas is introduced to harvest the ice. To maintain proper harvest temperatures, typical discharge gas pressure is 160 psia. This drives the liquid refrigerant in the tube up into an accumulator and melts the inside of the tube of ice, which slides down through a sizer and mechanical breaker, and finally down into storage. The defrost cycle is normally about 30 s. The unit returns to the freezing cycle by returning the liquid refrigerant to the tube from the accumulator.

This type of ice maker operates with R-717, R-404A, R-507, and R-22. R-12 may be found in some older units. Higher-capacity units of 10 tons per 24 h and larger usually use R-717. The capacity of the unit increases as the terminal suction pressure decreases. A typical unit with 70°F makeup water and R-717 as the refrigerant produces 19.3 tons of ice per 24 h with a terminal suction pressure of 38.5 psia and requires 35.7 tons of refrigeration. This equates to 1.85 tons of refrigeration per ton of ice. The same unit produces 41.6 tons of ice per 24 h with a terminal suction pressure of 21 psia and requires 80 tons of refrigeration. This equates to 1.92 tons of refrigeration per ton of ice. Figure 3 shows the physical arrangement for an ice maker that makes ice on the outside of the tubes.

Inside Tube. When ice is produced inside a tube, it can be harvested as a cylinder or as crushed ice. The freezing cycle ranges from 13 to 26 min. The tube is usually 0.9 to 2 in. in diameter, producing a cylinder that can be cut to desired lengths. The refrigerant temperature outside the tube is continually dropping, with an initial temperature of 25°F and a terminal suction temperature ranging from 20 to –5°F. At the end of the freezing cycle, the circulating water is shut off and the ice is harvested by introducing hot discharge gas into the refrigerant in the freezing section. To maintain gas temperature, typical discharge gas pressure is 180 psia. This releases the ice from the tube; the ice descends to a motor-driven cutter plate that can be adjusted to cut the ice cylinders to the length desired (up to 1.5 in.). At the end of the defrost cycle, the discharge gas valve is closed and water circulation resumes.

These units can use refrigerants R-717 and R-22; R-12 may be found in older units. Again, the capacity increases as the terminal suction pressure decreases. A typical unit with 70°F makeup water and R-717 as the refrigerant produces 43 tons of ice per 24 h with a terminal suction pressure of 40 psia and requires 74.5 tons of refrigeration. This equates to 1.73 tons of refrigeration per ton of ice. The same unit produces 66 tons of ice per 24 h with a terminal suction pressure of 30 psia and requires 135 tons of refrigeration. This equates to 2.04 tons of refrigeration per ton of ice.

Tubular ice makers are advantageous because they produce ice at higher suction pressures than other types of ice makers. They can make relatively thick and clear ice, with curvatures that help prevent bridging in storage. Tubular ice makers have a greater height requirement for installation than do plate or flake ice makers, but a smaller footprint. Provision must be made in the refrigeration system high side to accommodate the volume of refrigerant required for the proper amount of harvest discharge gas. Ice temperatures are generally higher than the temperature of flake ice makers.

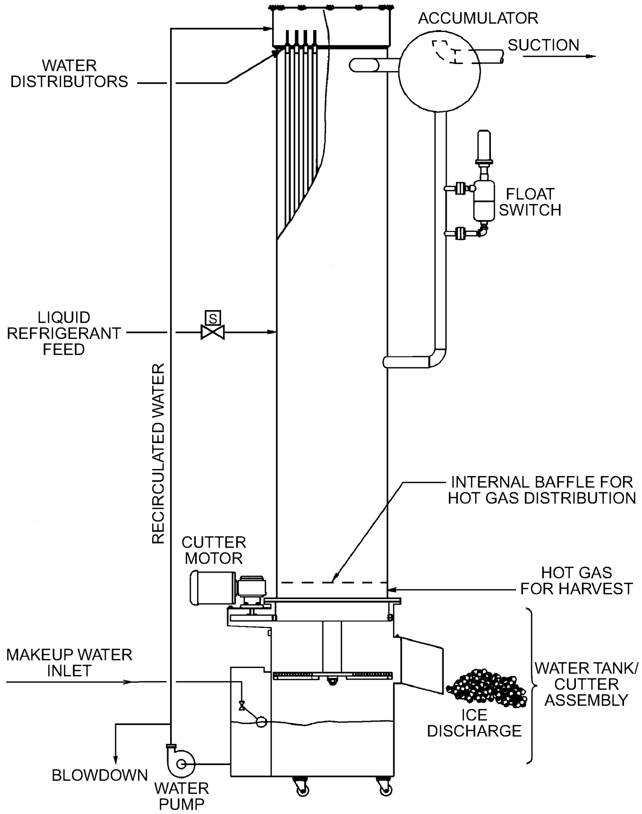

Fig. 3 Tubular Ice Maker

Supply Water. Supply water temperature has a great effect on the capacity of either type of tubular ice maker. If the supply water temperature is reduced from 70 to 40°F, the ice production of the unit increases approximately 18%. In larger systems, the economics of precooling the water in a separate water cooling system with higher suction pressures should be considered.

Plate Ice

Plate ice makers are commonly defined as those that build ice on a flat vertical surface. Water is applied above freezing plates and flows by gravity over the freezing plates during the freeze cycle. Liquid refrigerant at a temperature between –5 and 20°F is contained in circuiting inside the plate. The length of the freezing cycle governs the thickness of ice produced. Ice thicknesses in the range of 0.25 to 0.75 in. are quite common, with freeze cycles varying from 12 to 45 min. Figure 4 shows a flow diagram of a plate ice maker using water for harvest. All plate ice makers use a sump and recirculating pump concept, whereby an excess of water is applied to the freezing surface. Water not converted to ice on the plate is collected in the sump and recirculated as precooled water for ice making.

Ice is harvested from plate ice makers by one of two methods. One method involves the application of hot gas to the refrigerant circuit to warm the plates to 40 to 50°F, causing the ice surface touching the plate to reach its melting point and thereby release the ice from the plate. The ice falls by gravity to the storage bin below or to a cutter bar or crusher that further reduces the ice to a more uniform size. Plate ice makers using the hot-gas method of harvesting are capable of producing ice on one or two sides of the plate, depending on the design.

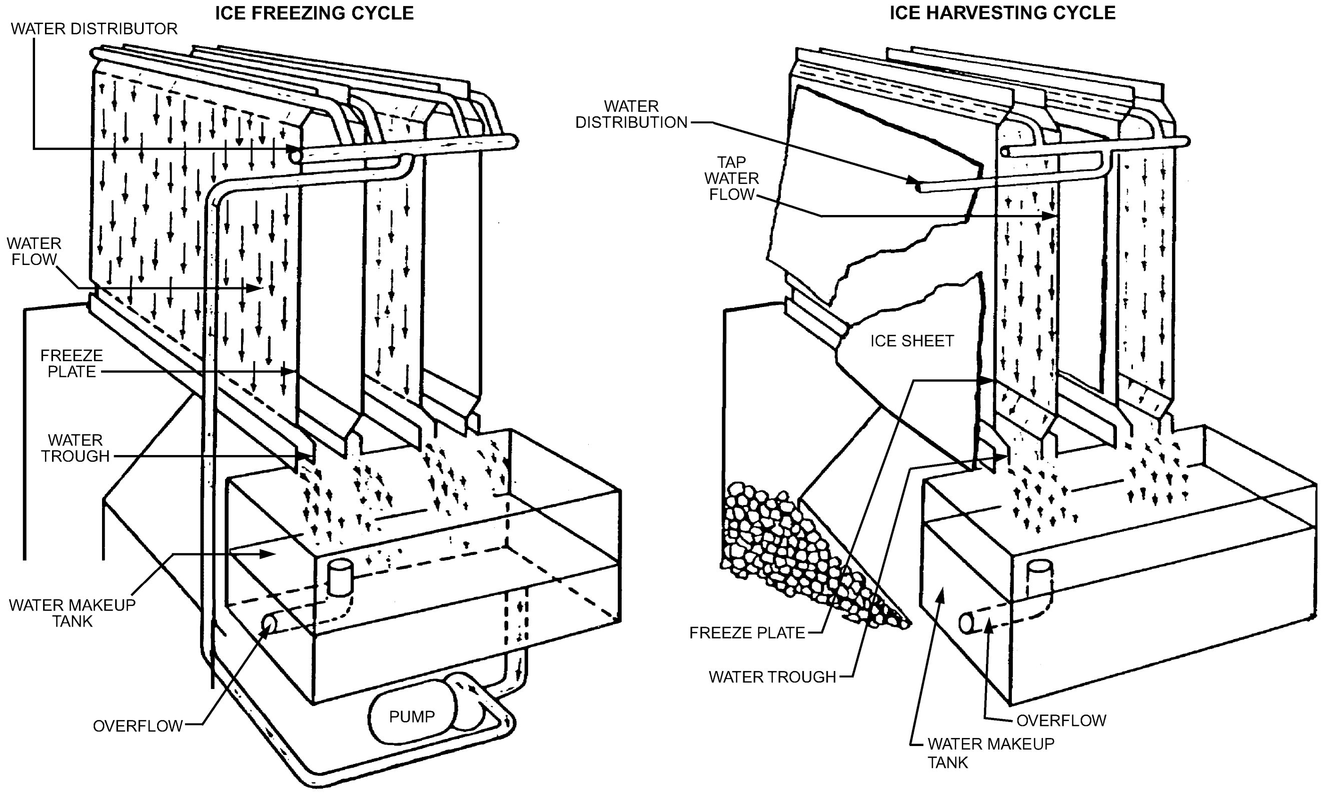

Fig. 4 Plate Ice Maker

In the second method of harvesting ice, warm water flows on the back side of the plate. This heats the refrigerant inside the plate above the ice melting point, and the ice is released. Ice makers using the water-warming harvest principle manufacture ice on one side of a plate only. Harvest water is chilled by passing over the plates. It is then collected in the sump and recirculated to become precooled water for the next batch of ice.

For plate ice makers, the freezing time, harvest time, water, pump, and refrigeration are controlled by adjustable electromechanical or electronic devices. Using the wide variety of thicknesses and freezing times available, plate ice makers can produce clear ice. Thus, the plate ice maker is commonly used in applications requiring clear ice.

Because of the harvest cycle involved, plate ice makers require more refrigeration per unit mass of ice produced than flake ice makers. This disadvantage is offset by the capability of plate ice makers to operate at higher evaporating temperatures; thus, connected motor power per ton of refrigeration is usually less than that of flake ice makers. During the harvest cycle, the suction pressure rises considerably depending on the design of the ice maker. When a common refrigeration system is used for multiple refrigerated requirements, a stable suction pressure can be maintained for all the refrigeration loads by using a dedicated compressor for the ice machine, or by using a dual pressure suction regulator at each ice machine to minimize the load placed on the suction main during harvest. This may occur in large processing plants, refrigerated warehouses, and so forth. Large plate ice makers can be arranged such that only sections or groups of plates are harvested at one time. Properly adjusting the timing of harvesting each section can reduce the fluctuation in suction pressure.

Plate ice makers using the water harvest principle rely on the temperature of the water for harvesting. A minimum of 65°F is usually recommended to minimize both harvest cycle time and harvest water consumption. For installations in cold water areas, or where wintertime inlet water temperatures are low, it is advisable to provide auxiliary means of warming the inlet water to 65°F.

Ice Builders

Ice builders comprise various types of apparatus that produce ice on the refrigerated surfaces of coils or plates submerged in insulated tanks of water. This equipment is commonly known as an ice bank water chiller. The ice built on the freezing coils is not used as a manufactured ice product but rather as a means of cooling water circulating through the tank as the ice melts from the coils. The ice builder is most often used for thermal storage applications with high peak and intermittent cooling loads that require chilled water. See Chapter 34 of the *ASHRAE Handbook—HVAC Applications* for more information.

Scale Formation

The performance of all ice makers is affected by the characteristics of the inlet water used. Impurities and excessive hardness can cause scale to be deposited on the freezing surface of the ice maker. The deposit reduces the heat transfer capability of the freezing surface, thereby reducing ice-making capacity. Deposited scale may further reduce ice-making capacity by causing the ice to stick on the freezing surface during the harvest process. The rated capacity of all ice makers is based on the substantial release of all the ice from the freezing surface during the removal period. Because the process of freezing water into ice tends to freeze a greater proportion of pure water on the ice maker freezing surface, impurities tend to remain in the excess or recirculated water. A blowdown, or bleedoff, whereby a portion of the recirculated water is bled off and discharged, can be installed. The bleedoff system can control the concentration of chemicals and impurities in the recirculated water. The necessity of a bleedoff system and the effectiveness of this concept for controlling scale deposits depend on local water conditions. Some refrigeration system loss is experienced because the recirculated water that is bled off to drain is precooled. Water that is bled off may be passed through a heat exchanger to precool incoming makeup water. Water conditions, water treatment, and related water problems in ice making are covered in Chapter 48 of the *ASHRAE Handbook—HVAC Applications*.

THERMAL STORAGE

Interest in energy conservation has renewed interest in the ice storage concept of providing thermal storage of cooling capacity for air-conditioning or process applications. The ice is produced and stored using lower off-peak and weekend power rates. During the day, stored ice provides refrigeration for the chilled water system. The design and features of thermal storage equipment are covered in Chapter 34 of the *ASHRAE Handbook—HVAC Applications*.

ICE STORAGE

Fragmentary ice makers can produce ice either on a continuous basis or in a constant number of harvest cycles per hour. The use of the ice is generally not at a constant rate but on a batch basis. Batches vary greatly, based on user requirements. The ice must be stored and recovered from storage on demand. Labor savings, economics, quantity of ice to be stored, amount of automation desired, and user delivery requirements must all be considered in ice storage and storage bin design.

Ice makers can produce ice 24 h a day. By making ice during off-shifts and weekends, as well as during work shifts, considerable savings in total ice-making and refrigeration system requirements can be achieved. In addition, by using electrical power during off-peak hours, peak loads on the power system are reduced during the day. Many power companies offer reduced rates during off-peak hours.

Ice storages vary in type from short- to prolonged-term. Degree of automation for filling and discharge ranges from manual shoveling to a completely automatic rake system.

Short-term storage generally requires provision for one day's ice production. The ice maker is mounted over a bin, and ice falls by gravity into the bin. The bin is an insulated, airtight enclosure with one or more insulated doors for access. Ice is removed from the bin by shoveling or scooping. In such storage, the subcooling effect of the ice generally offsets the heat loss through the insulated bin walls without excessive melting. In most situations, it is not necessary to provide refrigeration units in an ice storage bin where ice production is being used on a daily basis and ambient temperatures are reasonable.

Prolonged ice storage requires a refrigerated, airtight, insulated storage bin. Some designs provide for false walls and floor, which produce an envelope effect that allows cold air to circulate completely around the mass of ice in storage. If wet ice is placed in a bin refrigerated to a temperature below 32°F, it will freeze together and may be difficult to remove.

Time and pressure affect the storage quality of fragmentary ice. Even though a bin is refrigerated to a temperature well below 32°F, pressure can cause local melting near the bottom. Thus, there are limits to the size and configuration of a gravity-filled storage bin. The ice falling from an ice maker forms a cone directly underneath the drop in the bin. With slight variation because of the type of ice, the angle of repose is approximately 30°. Fusion of ice under pressure limits the practical ice storage depth to 10 to 12 ft. To use the volume of the bin more efficiently, a leveling screw mounted in the overhead can be used to carry the ice away from the top of the ice cone.

There is also a practical limit to the size of a storage bin from which ice can be manually removed through refrigerator doors. The simplest device used to remove ice from a bin is a screw conveyor with a trough at floor level, which is equipped with gratings and removable sectional covers. The removable covers protect the screw from ice blockage when the conveyor is not running. The gratings are for the protection of personnel.

Ice Rake and Live Bottom Bins

The ice rake system is used for larger and fully automated storages. These storages generally have a 10 to 300 ton capacity for a single rake system. Depending on plant demands, combinations of rake systems can be developed into an integrated production, storage, and delivery system. Such a mechanism could have capabilities of up to 1000 tons of storage with multiple screw or pneumatic conveying delivery systems. A range of delivery rates, up to 60 tons of ice per hour, can be achieved. The advantages of such rake systems are the elimination of labor for storing and transporting ice, longer and more effective distribution systems, faster delivery and termination of ice flow, less waste of ice, and the elimination of physical contamination.

Storages that incorporate rake systems are of two basic types. One type encloses the ice storage and rake system in an arrangement of steel framework and panels with the complete unit installed in a refrigerated room. The second type involves the construction of an insulated enclosure around the ice bin and rake system. This type can be installed inside a building or outside, depending on the weather protection provided. For either type, the ice makers are mounted outside of the refrigerated space. Figure 5 shows the arrangement of components for a typical rake system.

Once fragmentary ice comes to rest in the storage bin, it will not flow freely, and a mechanical force is necessary to start the ice moving. The deeper the ice is stored, the greater the pressure on the ice near the bottom. The ice near the bottom tends to fuse together faster. Rake systems work from the top of the ice; they continuously level and fill the storage bin, as well as automatically remove the ice on demand. The systems operate in nonrefrigerated or refrigerated bins; since most users of large storages also want ice to be dry for ease of handling, large automated storages are usually refrigerated.

The ice rake itself consists of a structural steel mechanism with drive. It operates similarly to the tracks of a crawler tractor. By means of a hoist and timer, the rake is raised or lowered to automatically maintain its position suspended over, and in close contact

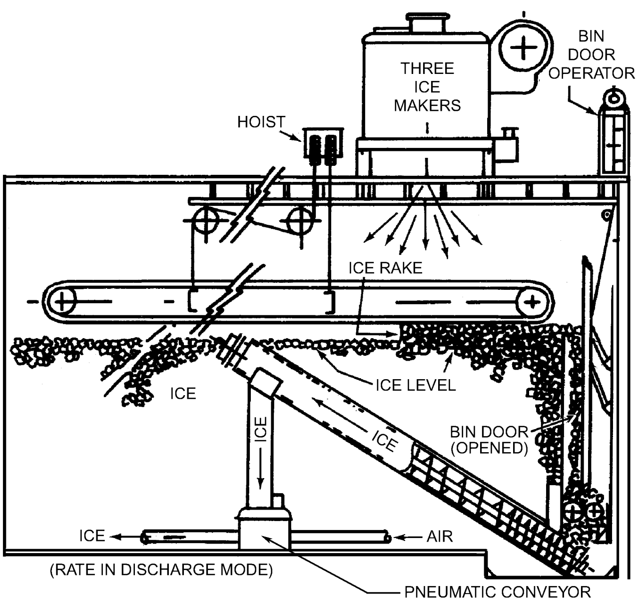

Fig. 5 Ice Rake System

with, the ice level. Wide scraper conveyors, mounted across the tracks along the full width of the bin, spread the ice out and drag it toward the back of the bin during the filling mode. To dispense the ice at delivery, the scraper conveyors reverse direction and drag the ice to the opposite end of the bin, dropping it into a screw conveyor mechanism. From this point, the ice is transferred to the external delivery system of screw conveyors.

Some rake systems have features that allow ice deliveries from the bin to be remotely controlled and volumetrically metered. Ice deliveries can be recorded on digital counters at the storage bin, remote stations, and control centers. Accuracy is in the range of ±2%. Another method of metering ice from a rake system storage involves the screw conveyor delivering the ice to a weigh belt. As the ice passes along the moving belt, it is electronically weighed and the weight is recorded. Selection of the belt material carrying the ice is critical in preventing ice from sticking to the belt. The weigh belt is often installed in a refrigerated area adjacent to the ice storage.

Another type of ice storage with delivery system capabilities is the **live bottom** type, with a multiplicity of screws arranged in various configurations on the bottom of the storage bin. Because of ice fusion, these bins are limited to short-term storage. The success of this type of bin depends on the type and quality of fragmentary ice being stored and the ability of the design to overcome particle fusion. Particle fusion may result in ice bridges forming over the top of the screws; then the screws will bore holes in the ice rather than empty the bin.

Primarily for the consumer bagged-ice industry, a bin and automatic storage system is used in which the entire floor moves, carrying the ice load into slowly rotating beaters. As the ice breaks loose, it drops to a screw conveyor, which feeds an ice bagger. This type of bin is located in a refrigerated room, and the ice makers are located away from the bin. The ice makers must be shut off so that no ice can flow into the storage during the discharge and bagging process.

The **ice silo** is used for long- or short-term storage with capacities in the range of 20 to 100 tons. The silo tank comprises a cylindrical part and a tapered, conical part leading the ice to the outlet at the bottom of the tank. From this point, the ice is transported by a screw delivery system. A rotating flexible chain arrangement is provided in the silo to assist in ice removal and to partially overcome the fusion problem. The ice maker is mounted over the top of the silo, and the ice falls into the storage. No leveling of ice is required in the bin because the diameter of the silo is sized to be compatible with the ice maker. The larger the ice storage, the higher the silo. As a result, proper ice discharge becomes more critical in the design when considering the fusion of ice and the fact that the ice must finally pass through a relatively small opening at the bottom of a tapered zone.

DELIVERY SYSTEMS

The location of ice manufacture is rarely the location of ice usage. Usually it is necessary to move ice from the ice machine or storage bin to some other area where it will be used; thus, a conveying system is required. Most conveyor applications use screws, belts, or pneumatic systems. Great care must be taken in selecting the size and type of conveyor to be used because no matter what type of fragmentary ice is being handled, problems such as fines, freeze-up, and ice jams can be encountered with an improperly designed system. Fines, or snow, are small particles of ice that chip off the larger pieces during harvesting, crushing, or conveying operations.

Screw and Belt Conveyors

Screw conveyors are the most popular of all the conveyances used for transporting ice. Screw conveyors are manufactured in sizes of 4 in. diameter and up, as well as in various screw pitches. Most ice-conveying operations use 6, 9, and 12 in. diameter screws.

The sizing and drive power requirements of screw conveyors are determined by the ice delivery rate, the inclination of the conveyor, and the conveyor screw pitch. With fragmentary ice, the selection of an undersized conveyor will result in excessive conveyor speed or require that the conveyor run too full of ice. These conditions can produce excessive fines.

When screw conveyors transport ice through high-ambient inside areas or outside in the weather (e.g., in icing fishing vessels), it is advisable to insulate the screw conveyor trough and provide the conveyor with insulated covers. Rain is as problematic as sunshine for contributing to ice meltage and delivery difficulties. For this reason, most screw conveyors operating in the weather are provided with sectional and removable covers.

Belt conveyors are often used when excess moisture has to be removed from the ice or to minimize the fines. The mesh belts allow snow and excess water to fall through. Stainless steel, galvanized steel, or high-density polyethylene are commonly used for belting.

Pneumatic Ice Conveying

Pneumatic ice conveying systems have proved desirable, economical, and practical for transporting fragmentary ice distances of 100 ft or more and when multiple delivery stations must be served. A pneumatic system is advantageous when delivery stations are in different directions or at different elevations, when delivery through a pressure hose is needed, or when flexibility is required for future changes or addition of delivery stations.

The basic principle of conveying ice by a pneumatic system involves a rotary blower, which delivers air to a rotary air-lock valve or conveying valve. Ice is fed into the conveying valve, and compressed air conveys the mixture of air and ice at high velocity through thin-walled tubing (aluminum, stainless steel, or plastic). Figure 6 shows the diagrammatic arrangement of pneumatic system components.

Delivery rates between 10 and 40 ton/h and conveying distances up to 600 ft are common. Delivery distances exceeding 600 ft can be achieved at reduced delivery rates, with the maximum practical distance being approximately 1000 ft. Conveying pressures range from 4 to 10 psig, depending on the delivery rate and the maximum distance the ice is to be conveyed. The air velocity required to keep the ice in suspension in the conveying line will vary among the different types of fragmentary ice. A pneumatic system cannot satisfactorily convey all sizes of fragmentary ice. The manufacturer of the ice-making equipment should be consulted for recommended line velocities. Sometimes, storage bins for ice plants using a pneumatic delivery system are refrigerated to ensure cold, free-flowing ice with minimum moisture. Because the ice remains in the tubing a very short time, tubing insulation is seldom needed or used. However, in warm climates, shading the conveying line reduces the solar load. The tubing typically used has a diameter of 4 to 8 in. and requires minimum support, making installation easy and economical.

Multiple delivery points are served by automatic Y-type diverter valves or multiple-way slide valves, either air or electrically operated. Pneumatically blown ice can be delivered under pressure out of the end of a hose. An alternative method of delivery is a cyclone receiver, which takes the ice at high velocity, dissipates the air, and drops the ice by gravity. Combinations of hose stations and cyclone delivery stations in the same system are common.

When a pneumatic conveying system is used in areas of high ambient and wet-bulb temperatures on an application requiring higher conveying pressures, a heat exchanger is often used to cool and dehumidify the pneumatic air before it enters the conveying valve. The heat exchanger is provided with a cooling coil, either refrigerant or chilled water cooled, a demister or other means of

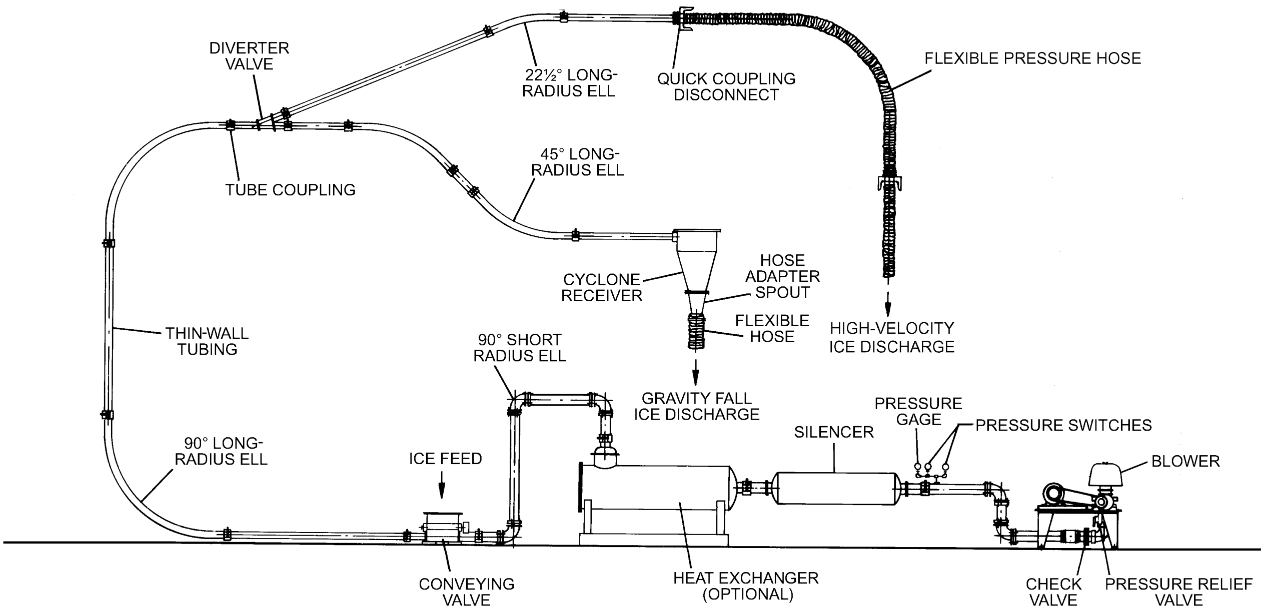

Fig. 6 Typical Flake Ice Pneumatic Conveying System

separating moisture from the air, and a condensate trap to expel the entrapped moisture. Geographical location, system pressure, and the quality and use of the ice at the delivery point must be considered when determining whether to use a heat exchanger.

Slurry Pumping

A mixture of particle ice and water can be pumped as a slurry. This method has some advantages for transporting ice. Generally, the slurry mix is approximately 50% water and 50% ice. For specialized application, mixtures of up to 80% ice and 20% water can be successfully pumped. Delivery distances of 800 ft have been achieved with delivery rates of 60 tons of slurry mix per hour. This practice has been extensively used in the produce industry and has potential in concrete cooling, chemical processing, and other ice or chilled water related applications. Ice slurry mixes are of particular interest where there is a need for low-temperature chilled water at or near 32°F. In converting ice to water, the absorption of latent heat at the usage point enables more cooling to be done with a slurry mix than with straight chilled water cooling. Pumping volumes and line sizes are minimized, and ice meltage during mixing and pumping does not normally exceed 1 to 3%. The system is capable of automation for continuous operation.

The basic system for slurry pumping includes a mixing tank, in which the ice and water are mixed. The ice is carried by any of the conventional conveying methods from the ice storage bin to the slurry mix tank. Agitators in the tank operate continuously to maintain a mixture with uniform consistency. Pumps discharge the slurry mix through pipelines to the point of use. The pumps are of the centrifugal type, modified for pumping slurry. When the icing cycle at the usage points is intermittent, a recirculating system returns unused slurry to the mixing tank. Thus, the slurry is kept moving at all times, and the possibility of ice blockage in the lines is minimized. The temperature of the slurry solution in the tank is maintained at 32°F.

The fresh produce industry offers a unique application for slurry mixes. Body icing of the fresh produce, which is generally of nonuniform size and configuration, is achieved by applying the slurry mix to the dry packed product. Drain holes are provided in the shipping container to remove water. Because of its suspension in water, ice is carried to all parts of the container. The ice solidifies as the water drains from the container. The product is then completely surrounded with ice, the voids are filled, and potential hot spots are eliminated. The drained water can be collected and returned to the mixing tank.

COMMERCIAL ICE

Commercial ice is primarily used for human consumption. It is also called **packaged** or **consumer** ice and is used for cooling beverages and for other applications in restaurants, hotels, and similar institutions. This use requires packaging at the ice plant for storage and eventual distribution. In bagged form, commercial ice is also available for sale in grocery stores and in automatic, coin-operated vending machines. When the ice is to be used in beverages, ice produced by plate or tube ice makers is preferred because of the clear appearance and the fact that it can be made in greater thicknesses. Rake systems are often used to store packaged ice and convey it into the packaging system.

Packaging. A packaging system normally comprises an ice bagger and a bag closer. These components are available from ice packaging equipment manufacturers in various types and sizes. In the bagging process, the ice is fed from the ice storage bin into the bagging machine by a screw or belt conveyor. The bagging machine meters ice into a bag placed below its discharge chute. The amount of ice measured into the bag can be determined by weight, volume, or sight approximation, depending on the equipment used.

When packaging by weight, the ice bag is placed on a weighing table on the bagging machine. Ice is then dispensed into the ice bag until the desired weight is in the bag. At this point, a switch mounted on the scale stops the flow of ice.

The volumetric bagging machine deposits the ice in a rotating chamber, which is adjustable in volume. After a predetermined volume of ice enters the chamber, the ice is discharged into the bag below. Because the shape and size of the ice is not constant, the volumetric chamber is usually set to produce a 3 to 5% overage by volume. Therefore, the proper minimum weight of ice in the bag is ensured.

The bag closer consists of a mechanical unit that ties and seals the top of the bag with a wire ring, wire twist tie, or plastic clip. Smaller bagging operations do not use a bag closer, and the bags are manually closed with plastic ties, wire rings, staples, and so forth. In more elaborate systems, the bag is formed from roll stock, filled with ice, automatically removed from the bagging machine, and automatically closed before it is dropped onto a conveyor, which carries the bagged ice to the refrigerated storage room. The degree of automation for the bagging and closing operation is determined by the number of bags of ice to be produced per day, the size of the bags, and the cost-benefit relationship between automated equipment and reduced labor costs.

Ice bags are made of plastic, most often polyethylene, or, very rarely, heavy moisture-resistant paper. Plastic bags are used in most modern plants.

Storage. Packaged ice must be stored in a refrigerated warehouse or room prior to distribution. The ice storage area is sized to meet the daily production of the plant and the distribution requirements. Generally, a bag ice storage facility can store 3 to 7 days' production. Although the ice will not melt at a storage temperature below 32°F, it is important that the storage be maintained at a temperature between 10 and 25°F. The lower temperature subcools the ice and avoids meltage during distribution. Depending on the type and quality of the ice, the bagged ice can contain some water. The percentage of water can range from 0 to 5%. For this reason, provision is made in the storage room refrigeration system for the product load of refreezing the water.

ICE-SOURCE HEAT PUMPS

Ice-making systems can be configured to provide heating alone, or heating and cooling, for a building or process. The conversion of water to ice occurs at a relatively high evaporator temperature and coefficient of performance compared to air-source heat pumps operating at low ambient temperatures. Systems can provide necessary heating, with the resulting ice disposed of by melting with low-grade heat, such as solar. In addition, ice can be used for useful cooling through daily, weekly, or seasonal storage.

The concept was originally considered mainly for residential heating and cooling, but installations are proving feasible for larger structures, such as office buildings. Energy consumption savings resulting from the coefficient of performance of a conventional heat pump system are achieved. Using off-peak night and weekend rates can reduce power costs, and the ice produced is used for building cooling requirements. As a result, a system can be developed that consumes less energy at a lower utility rate.

Ice-source heat pumps follow two basic approaches. The first involves using the ice builder principle, with coils in a large tank, as the evaporator component of the heat pump. The second approach uses a fragmentary type of ice maker as the evaporator, with ice being stored in a tank as a mixture of ice and water. Many variations, combinations, and adaptations may be developed from these basic systems. The requirement for thermal storage of a large quantity of ice dictates new planning in architectural building design. Heating and cooling system designs for the building are also influenced.

BIBLIOGRAPHY

Dorgan, C.E. 1985. Ice-maker heat pumps operation and design. *ASHRAE Transactions* 91(1B):856-862.

Dorgan, C.E., G.C. Nelson, and W.F. Sharp. 1982. Ice-maker heat pump performance—Reedsburg Center. *ASHRAE Transactions* 88(1):1271-1278.