Ice Making for Curling

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Ice is seemingly simple—just bring water to a temperature below 32°F (0°C), and you are done. Unfortunately, a number of sporting enthusiasts would respectfully disagree. Just think about those sports whose performance relies on “perfect” ice: hockey, figure skating, and curling. Each has a different definition of “perfect” ice, and curlers are often considered the biggest divas of the bunch, possibly for good reason.

Curling, a sport whose popularity peaks during the Winter Olympic Games, is often described as chess on ice. It’s a sport particularly well-suited to individuals who are strategy-minded, detail-oriented, and enjoy the cold. For a description of the basics of the game, see the sidebar “The Game of Curling.”

A single curling game’s ice sheet varies in size but is generally 150 ft (46 m) long by 15 ft (4.5 m) wide,\(^1\) as shown in Figure 1. A small club will have two to three sheets, while larger U.S. clubs run six to eight sheets. Thus, a standard six-sheet club will have an ice surface around 150 ft (46 m) long by 90 ft (27 m) wide. Typical refrigeration load averages 6 tons to 8 tons (21 kWT to 28 kWT) per sheet. Part of the refrigeration load arises from the participants, but the bulk is from heating the air for comfort and improved ice conditions.

The ice sheet for curling is not flat, but a surface littered with “pebbles” of ice. Prior to the start of any game, a shower of water droplets is dispersed across the playing surface (ice sheet), as shown in Photo 1. As the water droplets rapidly freeze, they create an uneven surface. In proper preparation of the ice sheet, the pebbling would then be “broken,” or have the peaks shaved off, to give an even top surface of plateaus with a variation of gaps below. The size of the water droplet, temperature of water applied, and the intensity of the spread of water spray all affect the profile of the surface. The variables are chosen based on the experience and preference of the club’s head ice maker. It seems that no two ice makers can agree on all three variables, as each has his own methods.

The Curl

Part of the phenomena of curling comes from the shape and size of the stone. It is an approximately 42 lb (19 kg) piece of 3 ft (1 m) circumference granite that has a

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handle on top, similar to a teakettle (see photo in sidebar, *The Game of Curling*). It contacts the ice on a 5 in. (130 mm) diameter circle of stone that is 0.25 in. to 0.5 in. (6 mm to 13 mm) wide called a running band. The running band surface area coupled with the stone’s weight results in a contact pressure of -1,500 lb/ft² (72 kPa). This heavy weight on top of a small contact surface on the ice is sufficient to reduce the friction of the ice, possibly by melting, allowing the stone to move easily down the sheet.

The exact mechanics of how the curl (rotation) of the stone affects the stone’s path of travel is still up for debate. But, the stone will move in a lateral direction to the path of travel in the same direction as its rotation. In other words, if the curler twists the stone in a clockwise fashion, it will curl to the right with the bulk of the sideways distance covered at the end, as the velocity of the stone slows.

It is also evident that even after the stone has been flung, the path of travel can be influenced by the sweepers. The sweeping action, as shown in Photo 2, warms the ice by a few degrees. Since this warming effect occurs evenly across the entire contact surface of the stone, it decreases the rotational effect and allows the stone to travel a bit farther.

Thus, a stone thrown too lightly can be carried an extra 6 ft to 12 ft (2 m to 4 m) by good sweepers, or the curl can be held off long enough for a stone to pass around a guard stone blocking its path of travel. Unfortunately, no method is available to cool the ice, so a stone that is thrown too fast cannot be slowed down, nor can a stone thrown too wide be induced to curl more.

**Effect of Debris, Ice Temperature and Frost on the Game**

As previously mentioned, proper curling stones are 42 lb (19 kg) of granite that ride across the ice on a thin running band. A stone thrown to land in the center of the house will travel at an average speed of 3 mph to 4 mph (5 km/h to 6 km/h). With this much weight and so little material in contact with the ice, any foreign debris on the ice surface itself or change in ice conditions will drastically affect the speed and path of the stone.

Typical results of foreign objects on the ice can range from a rattling of the stone as it quickly slows, to an early stop, to a change of direction either from the curl of the stone reversing or the debris pulling the stone in a new direction. In either case, the stone is usually useless to the team, as it either falls short of the playable field or careens out of bounds and is removed from play.

To combat the problem of foreign material, curlers often have special shoes dedicated to the sport that are kept extremely clean, lint-free clothing, and playing equipment that is cleaned prior to entering the ice house. Something as simple as pocket lint, a human
hair, a pebble from a shoe, or dirt shook off a broom can affect the stone’s performance.

Though not extensively documented, curlers well understand that mid-game adjustments in ice temperature can also drastically affect the play of the game. It is generally accepted that warmer ice surface temperatures (ISTS) will give faster ice, similar to warming the ice with the sweeping action, causing the stones to carry farther and straighter. The typical range for ice surface temperature is 21°F to 25°F (approximately –6.1°C to –3.9°C), though some ice makers prefer ISTs outside this range.2 Regardless of the initial temperature, curlers prefer consistent conditions throughout the games, so they can reasonably predict the stone’s path. If the IST changes by more than a degree, the predictability of the stone will be lost. To prevent this, curling clubs will often maintain a very low-temperature difference between the supply and return of the secondary refrigerant (e.g., glycol, calcium chloride) circuit buried in the slab beneath the ice sheet.

The most prevalent annoyance to curlers is formation of frost on the sheet’s exposed surface. Frost on the surface of a curling sheet is equivalent to spreading fine grit sand over the entire surface. Its presence slows the stones down by increasing the friction, while reducing the curl of the stone. The truly horrible aspect of frost on the game is that it can develop very quickly due to changing ice and/or air conditions mid-game. This is very upsetting to the curling divas, and they will express their displeasure quite vocally to the head ice maker.

Frost is formed when the surface temperature of the ice drops below the dew point of the air in the ice house. Depending upon the unloading capability of the compressors and secondary refrigerant (e.g., glycol, calcium chloride) pumping system, the ice surface temperature can rapidly swing a couple degrees when a compressor kicks on. Likewise, depending upon the dehumidification capability of the club, eight large, sweaty curlers per sheet can quickly raise the absolute humidity, and subsequent dew point, of the ice house.

To get a handle on this concept, Table 1 shows the dew point for a variety of typical ice house air conditions. Curling clubs that have some form of space heating available often try to hold a temperature around 40°F (4°C) and a relative humidity in the 30% to 40% range.

If a club were able to hold 40°F (4°C) with an ice surface temperature (IST) of 21°F (–6°C), at what relative humidity (RH) would frosting occur on the ice sheet surface? Looking at Table 1, under the conditions of 40°F (4°C) and 40% RH, the dew point is 18°F (–8°C). Said another way, no condensation of moisture from the air will occur on the ice sheet because the air dew-point temperature is less than the IST of 21°F (–6°C).

Moving down the table to 40°F (4°C) and 60% RH, the dew point is now 27°F (–3°C). So, at this room condition, moisture from the room air will condense onto the ice sheet surface in the form of frost. Assuming the ice sheet surface temperature is 21°F (–6°C), the room air condition that will just begin to form frost on the ice surface is 40°F (4°C) and 46% RH (having a dew point of 21°F [–6°C]). So frost will form on the ice whenever the air is 40°F (4°C) and the RH is 46% or higher.

As most curling facilities do not have adequate dehumidification capabilities within their ice house, maintaining the air at appropriate conditions to prevent frost formation on the ice sheet is difficult and sometimes impossible. This results in shortened seasons during years when the spring is unseasonably
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warm. On the other end of the moisture spectrum, it is possible to install too much dehumidification. A few curling facilities have installed desiccant dehumidification capacity similar to what is expected at a hockey facility operating year-round.

Without instruction or experience, the unknowing ice maker turns the system on at full capacity and soon the curling divas are upset. The extreme drop in moisture causes the air to sublimate away the pebbles that were expertly applied to the ice. This manifests itself first in a reduced curl and then transitions to chaos as the ice flattens out. Caution should be taken when sizing and operating dehumidification to ensure that the ice house dew-point temperature can be maintained just below the IST.

Ceiling Condensation

If frost on the ice is the bane of the curling diva, then condensation on the ceiling is the curse of all ice makers. Moisture that condenses on the ceiling rarely stays there, inevitably dripping onto the ice. If the condensation drip pattern is diffuse, the ice maker will find a number of smooth spots scattered across the ice, necessitating additional scrapings of the ice surface. If the drip is in a consistent pattern, the ice maker will find an ice sheet with stalagmites of ice. The author has witnessed some of these erratic ice structures to have grown to 0.5 ft (152 mm) overnight. The key to preventing ceiling condensation is to keep the ceiling temperature and the dew point far apart by managing the moisture content of the air.

Ceiling condensation is particularly bad during ice making. Ice is put down in layers either by flooding the surface with a thin layer of water or misting the water on. Misting is primarily used to start the ice sheet out and to lock in the water-soluble paint used to color the ice. During the misting process, large amounts of moisture are absorbed by the air.

Managing Moisture

The many ways to manage moisture in the ice house fall into two basic categories: moisture prevention and altering the ice house conditions.

Moisture Prevention: Properly Seal the Ice House

The first step to managing moisture should focus on preventing it from entering the ice house in the first place. While this sounds relatively simple, it is more difficult than it appears, as curling facilities are often repurposed facilities. Curling rinks can be found in everything from a former ore processing facility to a pig barn of the past.

Finding and sealing every moisture infiltration source in these reused facilities can be extremely difficult. Start with the skin of the building. If a vapor barrier was not initially installed, try to find a way to retrofit one into the structure.

Step two is to tackle the normal openings into the facility. Annually, weather stripping of doors, windows and
other access points to the ice house should be inspected and replaced if necessary.

The final step is to train the facility’s patrons on proper door management. Doors should be used as little as possible and never left open. Emergency doors should be treated as such and not as an alternative exit to the ice house.

**Alter Ice House Conditions: Increase Air Temperature**

Relative humidity is roughly defined as the ratio of the actual amount of moisture in the air over the maximum amount of moisture the air can hold. Since warm air can hold more moisture, the relative humidity (RH) can be decreased by increasing the air dry-bulb temperature. Increased air temperature will increase the ceiling surface temperature, thereby decreasing the potential for condensation and dripping.

Unfortunately, this is an indirect fix. A more direct fix is removing the moisture from the air to lower its dew-point temperature. As the air temperature is reduced to its normal conditions, the added moisture in the air will drop out in the form of condensation or frost unless other means have been used to remove the moisture.

**Moisture Removal: Using Outside Air**

Since most curling clubs are located in the northern regions of the U.S., Canada, and Europe, one option for moisture removal is to introduce larger amounts of dry outside air present during the bulk of the curling season. During the winter, air significantly below freezing will have very low absolute humidity levels. Increasing the amount of dry outdoor air being brought into the ice house will lower the absolute humidity level (and dew-point temperature) of the air. The downside to this option is that the cold outdoor air must be sensibly heated to both maintain the same air dew point and for occupant comfort. Depending upon the outside air temperature and the volume of air brought in, this option can get expensive.

On new construction, this option is often planned for in the construction of the space conditioning system. The only limitation is that local ventilation codes should be checked to ensure the dehumidification is capable of handling the added humidity that enters via code-minimum required ventilation.

Many older existing curling clubs do not have controlled ventilation, but rather plenty of infiltration.

While most of this is true infiltration, some control can be exerted by opening doors and windows.

**Moisture Removal: Install Vapor Compression Dehumidifiers**

Probably the best method to actively control moisture in curling facilities is to remove it with a dehumidifier, most commonly using a vapor compression dehumidifier but occasionally with a coil using the same secondary coolant as the ice. The basic principle is that the coil will decrease the temperature of air low enough to remove the excess moisture and then reheat the air back to its set temperature. This results in air that is considerably drier without changing the ice house set temperature.

The problem with this approach arises when we examine the rated capacity of the commercially available refrigerant-based dehumidifiers. Dehumidifiers are rated in pints (liters) per day of moisture removal at the specific conditions of 80°F (27°C) and 60% RH.

As the air temperature coming into the unit drops, its capacity (i.e., ability to remove moisture) decreases considerably. Many of the units installed in the curling clubs during the 1990s and 2000s had their capacity bottom out at 40°F (4°C) and 50% RH. Air at 40°F (4°C) and 50% RH has a dew point of 23°F (–5°C); therefore, in a curling facility equipped with older dehumidifiers, it is necessary to maintain an IST above 23°F (–5°F) to prevent frost formation.

If the IST is less than 23°F (–5°F), when the dehumidifier runs, it is wasting energy because it isn’t actually removing any moisture. Instead, the ice surface will do the dehumidification in the form of frost.
If a vapor compression dehumidifier is being installed, be certain to check its rated capacity at the temperatures and relative humidity you wish to achieve. It will be more expensive than other options since the unit is pulling to lower temperatures and using a defrost cycle to melt any frost building on the coils.

Moisture Removal: Desiccant Dehumidifiers

Active desiccant dehumidifiers found in larger hockey facilities, ice arenas and refrigerated warehouses are now finding their way into curling facilities. These dehumidifiers use a desiccant material on a honeycombed wheel that slowly rotates its contact time between the ice house air and a section of regeneration air.

Desiccant dehumidifiers have two advantages over vapor compression units. First, the capacity is relatively unaffected by temperature, so at any air temperature conditions, the unit will still have the capability to remove moisture. Second, the air leaving the unit will not only be drier but will also have a higher temperature. The temperature increase comes primarily from the heating of the wheel during the regeneration process. Since curling facilities rarely have a heat load higher than the cooling capacity of the refrigeration system, this extra heat will help offset the capacity needed from the heating system.

For those facilities considering adding a desiccant, beware of “typical” industry sizing calculations. The dehumidification needs of a year-round hockey facility with audience seating will be significantly higher than those of a seasonal-use curling facility. While little data exists on the exact capacity needed, anecdotal evidence indicates a desiccant output in the range 100 cfm to 200 cfm (170 cfm to 340 m$^3$/h) per sheet is sufficient.

If excessive desiccant capacity is installed, operation of the unit can be detrimental to ice quality. The unit may repeatedly cycle around the relative humidity setpoint, resulting in wide swings in RH. Or the unit may run continuously, causing sublimation of the surface pebble. Likewise, be certain the dry air leaving the desiccant is not pointed directly at the ice, which will cause localized sublimation.

Recommendations

Unlike refrigerated warehouses and large ice arenas, curling clubs are seasonal-use facilities with their own sets of challenges. Prior to compressor start-up for the season, make every effort to remove moisture that has built up in the walls, boards, and concrete of the facility over the summer. Much of this moisture can be easily removed using traditional vapor compression dehumidifiers operating for one to two weeks prior to compressor start-up. Seal the building up as per normal operation, repair any damage to weather stripping and turn on the dehumidifier. If dehumidification does not exist, consider renting portable units. Continue to use all dehumidification capacity throughout the ice-making process.

During the season, take steps to remove moisture from the ice house air whenever possible. If vapor compression dehumidifiers are the only technology available, develop a cycle of warming the ice temperature and air temperature to increase the dehumidifier capacity while reducing overnight frosting. This process can be automated through the use of programmable thermostats/controllers. If outside conditions are favorable, consider drawing in controlled amounts of outdoor air to reduce humidity.

If the budget exists, consider installing a desiccant dehumidifier. These units will provide frost protection throughout the season regardless of the air conditions in the ice house. Again, beware of following sizing guidance based on year-round hockey arenas. A curling facility’s maximum humidity load during the bulk of the year is the moisture put off by eight sweaty guys per sheet, not a stadium full of spectators and infiltration of humid summer air. Data currently being gathered should result in sizing guidance in a future publication.

In summary, every ice maker is looking for the magic method for creating the perfect curling ice. They focus on ice temperature, scraping methods, pebble size, water purity and many other variables. While these all affect the quality of the ice, the factor most often overlooked is the air that is in constant contact with 100% of the surface of the ice. Take time to understand the effects of air on the ice and how to control that air to the playing condition’s benefit.

References

2. 2014 ASHRAE Handbook—Refrigeration, Chap. 44.
10.8 Moisture Removal Efficiency
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